Inventory of existing treatment technologies in wastewater treatment plants

Case studies in four coastal regions of the South Baltic Sea
Poland, Sweden, Lithuania and Germany

Project MORPHEUS 2017 - 2019
Deliverable 5.1

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Key facts of the MORPHEUS project

MORPHEUS (Model Areas for Removal of Pharmaceutical Substances in the South Baltic) is a project financed by the European Union Interreg South Baltic Programme 36 months. The project duration is January 2017 – December 2019, with a total budget of EUR 1.6 million with a contribution from the European Regional Development Fund of EUR 1.3 million. The project has a total of 7 partners from four countries; Sweden, Germany, Poland and Lithuania: Kristianstad University (Lead Partner) – Sweden, EUCC – The Coastal Union Germany – Germany, University of Rostock – Germany, Gdansk Water Foundation – Poland, Gdansk University of Technology – Poland, Environmental Protection Agency – Lithuania and Klaipeda University – Lithuania. The project also has a total of 10 associated partners from these countries. For additional information on the project and activities please visit the MORPHEUS homepage at: www.morpheus-project.eu

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Summary

The occurrence of pharmaceuticals and other micropollutants in our water bodies is today well known as is the fact that most of these enter the environment via our wastewater treatment plants (WWTPs). This is mainly due to inability of existing technologies to remove them from the wastewater stream. The South Baltic Sea (SBS) is under pressure from a number of stressors including micropollutants such as pharmaceuticals, which is the background to the MORPHEUS project (Model Areas for Removal of Pharmaceutical Substances in the South Baltic). Proper wastewater management in WWTPs surrounding the SBS plays a crucial role in achieving a good water status and in the potential restoration of poor water resources. This report (Deliverable 5.1) aims at summarizing the status of existing technologies currently used in the wastewater sectors in a few selected WWTPs located in the coastal regions of Pomerania (Poland, PL), Skåne (Sweden, SE), Klaipeda (Lithuania, LT) and Mecklenburg (Germany, DE). In total 14 model WWTPs in Poland (4), Sweden (3), Lithuania (4) and Germany (3) were chosen.

A detailed survey of the selected WWTPs in model area has pointed towards the following priority and challenges:

In **Poland** the two large, automatically controlled WWTPs at Gdansk-Wschod (load 742 521 PE) and Gdynia-Debogorze (load 476 000 PE) are well equipped and managed. They contain a mechanical step and an advanced biological step, which is occasionally supported by a chemical step for phosphorus removal, so they fulfill all discharge requirements. Interestingly, in the past few years, an increasing share of inert chemical oxygen demands (COD) in the total COD entering both municipal WWTPs has been noted. This change might be connected to discharge of industrial wastewater to the municipal sewer, as well as with an increasing amount of chemicals used by households. However, wastewater originating from the healthcare sectors and hospitals in these areas might also play a role. Currently at Gdansk-Wschod WWTP and Gdynia-Debogorze WWTP, special attention is given to sludge management, in terms of implementation of separate treatment for nitrogen-rich wastewater from the sewage sludge dewatering processes after the anaerobic digestion (e.g. anammox process). This year, a serious malfunction of one wastewater pumping station, which belongs to the Gdansk-Wschod WWTP system, has highlighted the need for competent technical personnel and local authorities to properly handle such crises.

The two other WWTPs, located in Jastrzebia Gora (load 12 540 PE) and in Swarzewo (load 149 000 PE), also contain a mechanical step and an advanced biological step for simultaneous nutrients removal, with chemical precipitations to increase phosphorus removal. Due to their location in an agricultural area, both Jastrzebia Gora WWTP and Swarzewo WWTP have to accept wastewater collected from surrounding septic tanks, which is usually highly condensed, and thereby influence the treatment efficiency. They are also facing an increasing amount of wastewater during the touristic season from May to August.

In terms of pharmaceuticals and other micropollutants in the near future no investments are planned.

In **Sweden** Kristianstad WWTP (load 118 000 PE) is one of the major WWTPs in Region Skåne and contains all steps; mechanical, biological and chemical. It also has a final step applied with filtration of all treated wastewater through sand for a final polish prior to release. Kristianstad WWTP is presently also in a phase of major change to increase the population equivalent from 205 000 PE to 260 000 PE. This is needed to serve with the safe margin a growing number of inhabitants from Kristianstad Municipality (83 000 inhabitants) but also the large volumes of wastewater from surrounding food industries such as The Absolut Company (spirits), Scan (slaughterhouse), Skånemejerier (dairy) and Lyckeby Starch (starch and protein). Together these industries contributed to almost 70 000 PE or more than 60% of the treated wastewater. The high density of food production plants in Kristianstad Municipality coincides with very fertile soils and heavy agriculture in the plains surrounding Kristianstad. The reconstruction of Kristianstad WWTP will include the mechanical part of the facility as well as the biological and chemical steps.

The two minor treatment plants in Kristianstad Municipality are Tollarp WWTP (load 4 790 PE) and Degeberga WWTP (load 950 PE) which both have all steps; mechanical, biological and chemical. It could be noted though that Degeberga, just as Kristianstad, also has a final sand filtration step were all treated wastewater undergoes a final polish prior to release. Neither Tollarp WWTP nor Degeberga WWTP have any major changes currently planned on the existing treatment steps apart from minor adjustments.

A long-term goal in Kristianstad municipality includes implementation of advanced treatment technologies to remove pharmaceuticals and other micropollutants by filtration through activated carbon. A first step has been initiated at the minor WWTP in Degeberga to investigate the possibility of introducing the technology in a smaller scale. Thereafter, if successful, the technology could be transferred to the 200 times larger WWTP at Kristianstad WWTP. However, this is a process that will take several years to become reality.

In **Lithuania** a detailed survey of the four WWTPs indicated that Klaipėda WWTP (load 219 654 PE) and Palanga WWTP (load 19 926 PE) combine biological removal of carbon, nitrogen and phosphorus using the University of Cape Town (UCT) concept and the anaerobic-anoxic-aerobic process (A2O), respectively. At Kretinga WWTP (load 18 151 PE) and Nida WWTP (load 1 697 PE), they consist of a biological part, efficient in organic matter degradation and nitrogen removal, while the phosphorus is chemically precipitated. Despite the seaside location, the seasonal variability of sewage flow does not influence the treatment quality at the WWTPs, but requires higher operating costs. More noticeable on the treatment quality is the elevated infiltration rate, which reaches up to 60%. In the nearest future no changes are foreseen or planned at Nida WWTP, while at Klaipėda WWTP and Palanga WWTP the activated sludge processes are going to be modernized to increase the efficiency of aeration and nitrogen removal. At Kretinga WWTP a pilot module for removal of pharmaceuticals and other micropollutants is underway the coming year. Other investments, which are planned in the Lithuanian model area is to modernize and develop WWTPs serving up to 2 000 inhabitants.

Germany has a well-developed wastewater sector in terms of regulation, wastewater collection, and treatment effectiveness, with advanced nutrient removal required for all WWTPs with a load > 10 000 PE. Currently attention is also given to smaller, but numerous WWTP (>500), which are indicated as a sources of phosphorus dissemination in inland water bodies. In this project three WWTPs were investigated in the model area: the Central WWTP Rostock (current load 342 483 PE), Laage WWTP (12 658 PE) and Krakow/Charlottenthal WWTP (6 209 PE). All three WWTPs use the treatment method based on the activated sludge concept. At the Central Rostock WWTP the conventional activated sludge system is additionally supported by biological fixed film reactors, where clay is used as a filter material and carrier for the microorganisms. This method is effective in nutrients removal and reduce the sewage sludge production, which is highly needed, since due to the changes in legal settings the agriculture application of sewage sludge is limited for WWTPs larger than 50 000 PE. Besides nutrients, Germany is also regarded as one of the leading countries in the area of micropollutants removal. However the region of Mecklenburg-Western Pomerania has not yet implemented any advanced treatment steps of wastewater treatment, but topic is gaining increased attention among both researchers and public authorities.

Summary of similarities and differences in existing technologies

The studied model area of the MORPHEUS project in Poland, Sweden, Lithuania and Germany are ecologically very vulnerable and are therefore usually covered by the Natura 2000 network for nature protection in the European Union, but also global protective initiatives such as The Convention on Wetlands (the Ramsar Convention) for conservation and sensible use of wetlands and their resources. During this survey all regions reported that large WWTPs (> 10 000 PE) are well equipped and properly managed meeting the current requirements, not only on nutrients removal but also in decreasing the energy footprints. This is very important since at least in Poland and Germany, the large WWTP treat > 80% of the wastewater and are responsible for substantial emissions into the South Baltic Sea. Nonetheless, there are still some challenges related to the sludge managements, and specific technologies are planned in some countries. In Poland to treat the nitrogen rich wastewater rejected from sewage sludge processes and in Germany in terms of phosphorus recovery from wastewater.

The MORPHEUS model areas are in some cases subjected to the very intensive seasonal human pressure due to a large growth of tourism. Tourism requires a high standard of water supply and wastewater services, and possess a high pressure on the current water/wastewater infrastructure. The wastewater load from tourist resorts varies in a wide range with overload occurring within a few days and with peaks recorded in the summer season, or even during the weekend. These peaks influences mainly small town and villages, and from this point of view the smaller WWTP (< 2 000 PE) are decisive, especially when discharge occurs into small receiving water bodies. Additionally, the investigated model areas are rich in large wetlands, rivers and streams, which are cross-linked and therefore the occurrence and distribution of pharmaceutical residues in these areas are very important to describe at a regional and local level to better understand the needs for future investments in existing and advanced treatment technologies. In Germany WWTPs serving hotels, camping sites and private householders' tanks are currently upgraded to higher technological standards, while in some areas of Region Skåne smaller WWTPs are replaced with pumping station where wastewater is transported via pipes to larger, more advanced treatment systems. Additionally, in the model area of Germany and Sweden a fourth advanced treatment step for pharmaceuticals and other micropollutants removal is currently in the process of being implemented, at least in a large pilot scale, but with tentative future prospect of larger investments. Advanced treatment of pharmaceuticals and micropollutants at a pilot scale will also be implemented in Lithuania within short.

There is also a need for international knowledge transfer and cooperation between countries in the water/wastewater sector.

1. Introduction

Activated sludge processes were introduced as an effective technology in wastewater treatment one hundred years ago, when in 1914 Edward Ardern and William Lockett described the process of organic matter removal by suspended biomass. The biomass effectiveness was increased by their acclimation to the treated wastewater (activation), which was obtained by gravitational biomass separation from the treated wastewater and subsequent recycling. Since then activated sludge processes, in numerous variations, has become an integral part of wastewater treatment. This technology has faced major changes in worldwide population, urbanization and industrialization. Nonetheless, there are also disadvantages of the activated sludge process, such as considerable energy requirements, greenhouse gas emissions and limited efficiency in micropollutants removal. Thus, currently the processes based on activated sludge in the wastewater sector are being inventoried, to recognize and meet new challenges, as, for example, zero emission technology. Under these terms, the MORPHEUS project is focusing on the existing treatment technologies, with special attention given to their efficiency in pharmaceuticals removal.

Over the past few decades several regulations have been introduced into the EU wastewater sector, with the Water Framework Directive (WFD), the Urban Wastewater Treatment Directive and the Drinking Water Directive regarded as the most important. The WFD (2000/60/EC) concept sets out and aims to achieve a “good status” of all water bodies by 2015. Therefore, much interest has been directed to the occurrence and removal of micropollutants, due to mounting evidences that biological treatment based on activated sludge is an insufficient barrier for their removal. Among micropollutants, pharmaceuticals are of special concern due to the insufficient knowledge of their toxicity and impacts on humans and ecosystems. However, it has been increasingly recognized that continuous exposure even to low, subtoxic concentrations of certain pharmaceuticals may cause unexpected consequences and unintended effects such as problems with procreation and change in the genetic balance in fish population, change to the taxonomy and increase the antibiotic resistance among environmental bacteriocenosis. For these reasons changes in regulations and standards can be expected in terms of wastewater treatment and environmental monitoring the coming years.

The constant release of pharmaceuticals and other micropollutants via wastewater treatment plants (WWTPs) to the South Baltic Sea (SBS) is the background to the MORPHEUS project (Model Areas for Removal of Pharmaceutical Substances in the South Baltic). The project aims to combine information about pharmaceuticals consumption patterns with estimates of their discharge from a few selected WWTPs located in the coastal regions Pomerania (Poland, PL), Skåne (Sweden, SE), Klaipeda (Lithuania. LT) and Mecklenburg (Germany, DE),

The aim of this report (Deliverable 5.1) was to highlight the technologies currently used in the wastewater sectors in these regions. The model wastewater treatment plants (WWTPs) in Poland, Sweden, Lithuania and Germany were chosen to identify everyday parameters, maintenance and challenges as well as ongoing or future investments in the wastewater treatment facilities (Figure 1.1).

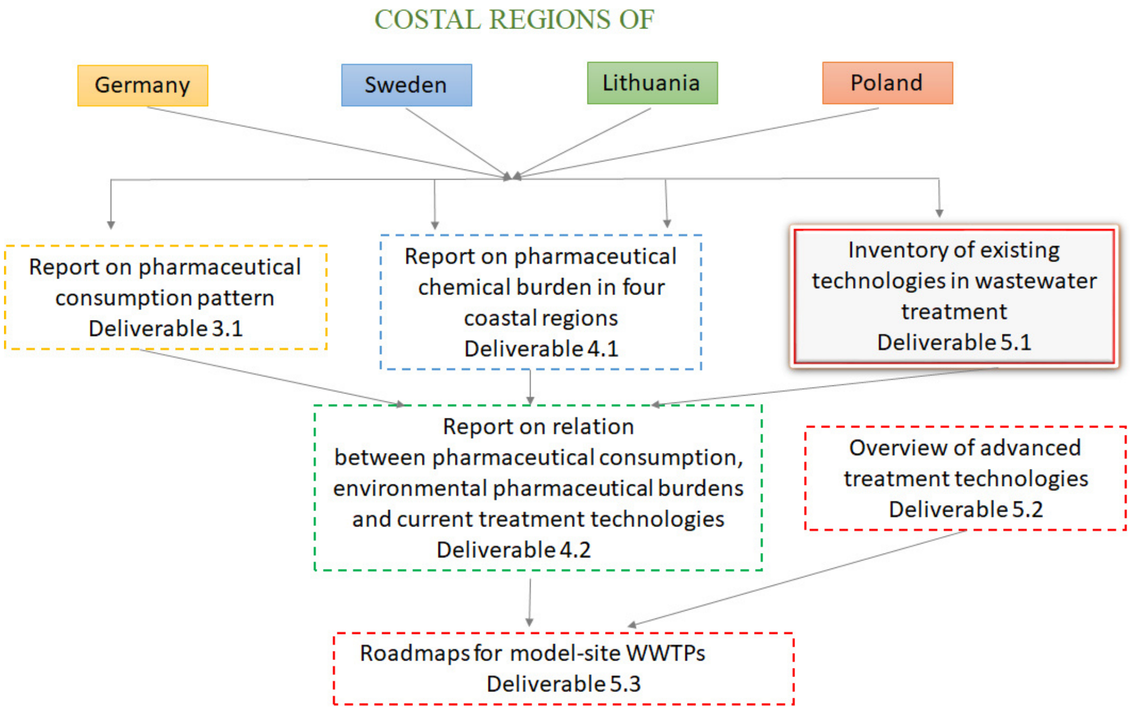

***Figure 1.1**. Inventory of existing technologies in wastewater treatment – visualization of Deliverable 5.1 in the context of MORPHEUS.*

MORPHEUS partners and Baltic Sea Catchments include the following four model areas:

- in Poland – Baltic Sea catchment within the Pomeranian Voivodeship, esp. the metropolitan area of Tri-City as well as the Czarna Wda catchment.
- in Sweden – Kristianstad municipality, Skåne County and the catchment areas of the lower part of the Helge Å river and Vramsån river (a tributary to Helge Å river) as well as Segesholmsån river catchment area. All rivers destination is Hanöbukten Bay, Baltic Sea.
- in Lithuania - Klaipėda County.
- in Germany – Baltic Sea catchment within the Federal State Mecklenburg-Vorpommern, esp. the sub-catchments of the rivers Warnow/Peene, Schlei/Trave as well as the German side of the Oder.

2. Survey on wastewater treatment in the model area of Poland - Baltic Sea catchment within the Pomeranian Voivodeship, esp. the metropolitan area of Tri-City as well as the Czarna Wda catchment (2015)

2.1 Pomeranian Voivodeship – general information

The Pomeranian Voivodeship (Polish: *Pomorskie*) is one of sixteen provinces of Poland, situated in the north, bordering the shore of the Baltic Sea. The Polish Model Area of the MORPHEUS project and the Baltic Sea catchment is given in Figure 2.1.

Figure 2.1. *Overview of the geographic position of the Polish model area Pomerania Voivodeship in relation to the Baltic Sea and the surrounding partner countries of the MORPHEUS project.*

The Voivodeship area is equal to 18 293 km^2 with and urban area of 106 761 ha, while the rural area is 1 724 273 ha (the source of data in this report is mainly Statistics Poland 2015*)*. The Pomeranian Voivodeship is divided into 20 counties (powiats): 4 city counties, and 16 land counties (Table 2.1).

Table 2.1. Basic data on the Pomeranian Voivodeship (in 2015); the counties, where model wastewater treatment plants (M-WWTPs) are located are marked in blue

No	English name of county	Area km^2	Population (in 2015)	Number of WWTPs
1	Bytowo County	2 193	78 916	16
2	Chojnice County	1 364	97 077	6
3	Czluchow County	1 574	56 748	9
4	Gdansk County with two city counties: Gdansk and Sopot	1 089	613 769	8
5	Kartuzy County	1 120	132 382	7
6	Koscierzyna County	1 166	71 958	15
7	Kwidzyn County	835	83 499	10
8	Lebork County	707	66 219	9
9	Malbork County	495	63 919	4
10	Nowy Dwor County	653	35 948	5
11	Puck County with one city counties: Gdynia	713	230 745	7
12	Slupsk County with one city counties: Slupsk	2 347	190 277	20
13	Starogard County	1 345	127 570	14
14	Sztum County	731	42 122	11
15	Tczew County	698	115 825	10
16	Wejherowo County	1 280	212 661	9
	Total	**18 310**	**2 219 635**	**160**

The total population of the Pomeranian Voivodeship was 2 219 635 in 2015: 1 478 802 in urban and 740 833 in rural area. The population density in the region is close to the national average (about 123 people /km^2), with strong intraregional differences – Tri-City metropolitan area (Polish: *Trójmiasto*) gathers around 32.6% of the inhabitants of the province on 2.26% of the province area (1 930 people/km^2). The Tri-City metropolitan is a special complex of closely-connected coastal cities. These are: Gdansk (459 919 residents), which is a thousand years old city and the capital of the Pomeranian Voivodeship, with high architectural and cultural values; Sopot (37 089 residents), with famous health and spa resorts and Gdynia (250 000 residents), a modernistic and one of the most dynamically growing Polish cities. The most important academic centers are also located in the Tri-City: the University of Gdańsk, Gdańsk University of Technology, Maritime University of Gdynia, Pomeranian University in Słupsk, Medical University of Gdansk, Naval Academy in Gdynia.

The economy of the Pomeranian Voivodeship is one of the most developed in Poland, combining recreational, agricultural and industrial areas. However cultural diversity as well as maritime and historical traditions, including solidarity is regarded as an important factor for local development. The ports of Gdansk and Gdynia are important transport hubs, which foster development of different types of production and services. Besides maritime industry and shipyards a number of other branches such as refinery, food, pharmaceuticals, cosmetics, furniture and transport are well developed here. The province is also very well prepared to welcome tourists all year round, offering possibility to visit seaside towns, beaches, historic port cities, teutonic castles, and a rustic countryside. In Pomeranian Voivodeship, however, different components of tourism should be considered: seasonal and commuting tourists. Commuting tourists are persons arriving and leaving on the same day such as cruise tourism, which is becoming more and more prominent in northern Poland. Unfortunately, the commuting tourists are not well recognized. The Pomeranian region has the largest accommodation bases in the country, which is, however, focusing on the coastal belt. The Vistula Lagoon as well as the Bay of Gdansk, and its shallow western branch Puck Bay, are characterized by very good weather conditions. It also provides excellent natural conditions for water sports (yachting, kitesurfing, kayaking etc). Pomeranian Voivodeship is located on the Vistula River at the bottom of its catchment.

The largest rivers of the voivodship include the tributaries of the Vistula: Brda, Liwa, Motława, Nogat, Radunia, Wda, Wierzyca, and direct tributaries of the Baltic Sea: Czarna Wda, Łeba, Łupawa, Reda, Słupia and Wieprz. Lakes of the Pomeranian Voivodship form clusters, and there are about 2 800 lakes with an area of over 1 ha. The rivers and streams are fed mainly by groundwater inflow. These systems are strongly cross-linked and characterized by the numerous small water bodies and ditches. The interactions of water bodies are very important in terms of pollutants dissemination, in particular in the Pomeranian Voivodeship, where the groundwater is the main source of water supply for municipal purposes and a supplementary source for industrial purposes.

2.2. Wastewater management in the Pomeranian Voivodeship

In the Pomerania Voivodeship the total water consumption was 200.3 hm^3 in 2015. Of these, 95.2 hm^3 (47.5%) was for industrial needs, for irrigation in agriculture and forestry as well as for filling and completing fish ponds 9.2 hm^3 (4.6%) was required, while for exploitation of water supply network 96.0 hm^3 (47.9%) was used. The consumption of water from water supply systems in households was 75.7 hm^3, with 51.4 hm^3 in urban and 24.3 hm^3 in rural areas. Importantly, it is estimated that in Poland approximately 25% of the rural population does not have access to public drinking water supply and uses small local systems or individual wells, with questionable chemical and microbiological quality. The water consumption per capita was 32.8 m^3, with 34.6 m^3 in urban and 29.7 m^3 in rural areas. The total amount of industrial and municipal wastewater discharged into waters or into ground was equal to 165.2 hm^3, including 81.3 hm^3 of wastewater discharged by the sewage network (municipal wastewater).

After accession to the European Union in 2003 Poland was oblige to harmonize the Polish law with European law, also in the wastewater sector. Currently the WWTP discharge has to fulfill the Polish Regulations, namely with the Regulation of the Ministry of Environment from 2014 on conditions of discharges into water and soil and on substances particularly hazardous to the aquatic environment, which came into force on the 1st of January 2016. These values match those of the Urban Waste Water Treatment Directive (91/271/EC) except for the Biological Oxygen Demand, for which the limit of the Polish regulation (15 mg/l) is actually more stringent than in the Directive (25 mg/l). The local authorities can, however, require higher efficiency of treatment, depending on the receiver status.

Polish accession to EU has caused a dynamic growth in the wastewater sector, especially in large municipalities. Currently in Poland the total number of municipal WWTPs is about 3 000, but still 25% of households have no access to the sewerage system. In the Pomeranian Voivodeship 83.2% of population is connected to WWTPs. There is a notable disproportion observed between urban and rural areas, where construction of centralized WWTPs is often considered as too expensive. Polish regulations, in fact, allow the use of small/individual WWTPs only if there is no existing sewerage system in the area. Such plants (< 5 m^3/d) can legally discharge effluent to soil or water within the limits of the owner's ground. In the rural area, however, the septic tanks are predominant and used mostly for wastewater accumulation. This type of wastewater is delivered to WWTPs by slurry/vacuum tanks and is usually higher contaminated than municipal wastewater reaching WWTPs via sewerage system. The septic tanks are often overflowing or leaking, causing contamination of groundwater resources. It is noted, however, that the number of septic tanks is decreasing, since they have been replaced with other on-site wastewater treatment systems, mainly biological household wastewater treatment systems. It should also be noted though, that in the reporting period of 2015, most WWTPs < 15 000 PE have no limits for nutrients and phosphorus removal, except direct discharge to lakes and artificial water reservoir (Regulation of Ministry of Environment from 2014). Since 2016 WWTPs in the range 10 000 – 15 000 PE should limit also nutrients, thus in the near future (the next 10 to 20 years) small WWTPs are intended to undergo modernization in terms of extensive nutrients removal or are intended to liquidation.

In the Pomeranian Voivodeship the total number of municipal wastewater treatment plants (WWTPs) is equal to 160 objects, which are estimated to serve 1 920 400 inhabitants and treat total load of 3 146 300 PE. The four largest WWTPs (>100 000 PE) in the region treat more than 63% of the total load (Table 2.2). The above statistics, given also in Table 2.2, show the nature of the problem in the wastewater sector, which is related to the dispersed collection and treatment systems.

***Table 2.2**. Overview of the wastewater sector in the Pomeranian Voivodeship and in the metropolitan area of Tri-City*

WWTP size (design size in PE)	Number of WWTPs	Total capacity (PE)	Share of treated load
wastewater sector in the Pomeranian Voivodeship			
< 2 000	80	62 926	2%
2 000 – 9 999	47	220 241	7%
10 000 – 14 999	15	409 019	13%
15 000 – 99 999	14	471 945	15%
>100 000	4	1 982 169	63%
Total	**160**	**3 146 300**	**-**
wastewater sector in the metropolitan area of Tri-City			
< 2 000	5	3 370	0.20%
2 000 – 9 999	6	37 207	2.17%
10 000 – 14 999	3	107 000	6.23%
15 000 – 99 999	-	-	-
>100 000	3	1 570 200	91.40%
Total	**17**	**1 717 777**	**-**

The WWTPs located in this region usually combines mechanical and biological treatment of wastewater with sewage sludge management. Four of them have been chosen as model wastewater treatment plants (M-WWTPs) in the MORPHEUS project, one WWTP is located in Gdansk County with two city counties: Gdansk and Sopot and three WWTPs are located in Puck County with the city county Gdynia as outlined below.

2.3. Model wastewater treatment plants (M-WWTPs)

The Polish part of the MORPHEUS project focused on the metropolitan area of Tri-City as well as the Czarna Wda catchment in the Pomeranian Voivodeship where four model wastewater treatment plants (M-WWTPs) were chosen for the survey of existing technology. The 4 model WWTPs were located in Gdansk-Wschod WWTP, Gdynia-Debogorze WWTP and Swarzewo WWTP (> 100 000 PE), which covers relatively large area and discharge treated wastewater directly to the Baltic as well as Jastrzebia-Gora WWTP (designed capacity 62 000 PE), which discharged to the Czarna Wda river. The geographical position of the M-WWTPs is shown in Figure 2.2 and Figure 2.3 and will be described in more detail below.

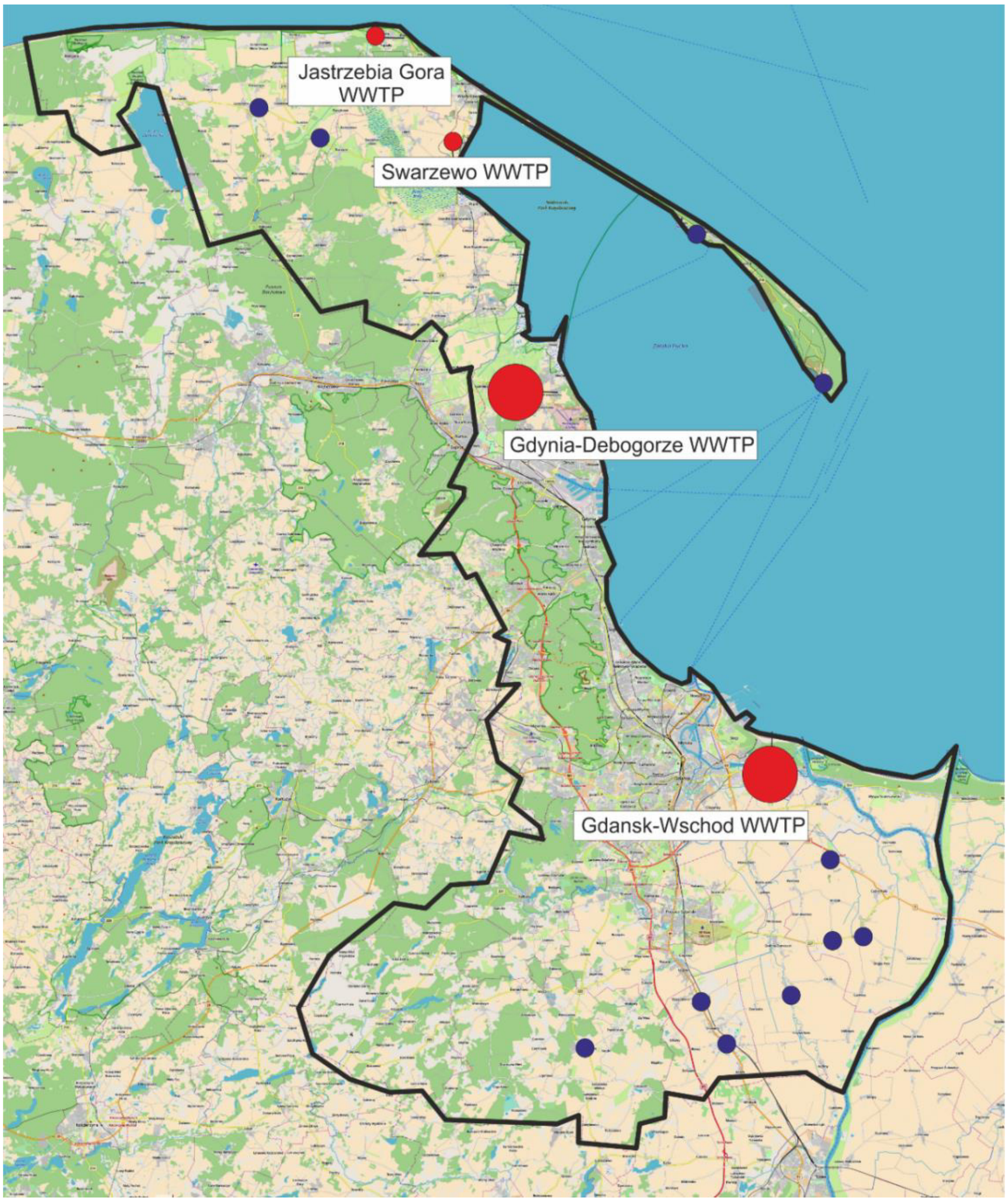

Figure 2.2*. Geographic position of Polish model area with the location of four M-WWTPs: Gdansk-Wschod, Gdynia-Debgorze, Swarzewo and Jastrzebia Gora (red circles), and other WWTPs in this area (blue circles)*

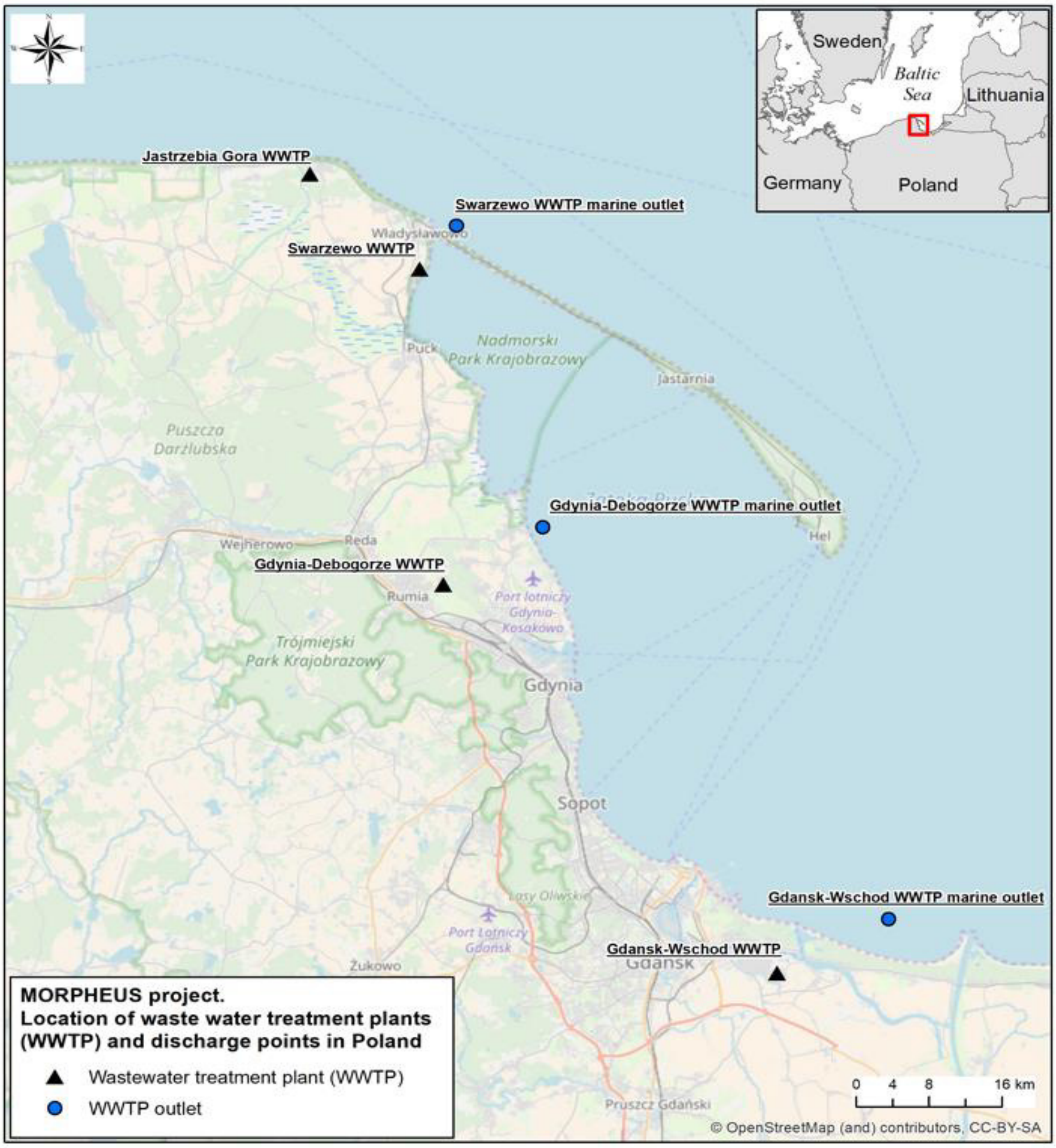

Figure 2.3. *Localization of M-WWTPs and their discharge points in model area of Region Pomeranian Voivodeship Poland.*

In this coastal region WWTPs are highly influenced by the tourists. The temporal growth of the population due to tourism causes the seasonal inflow to increase 1.5- to 7- fold in the summer, which is particularly noticeable in WWTPs with smaller sewer network, such as Swarzewo WWTP and Jastrzebia-Gora WWTP. Besides the hydraulic overload and other technological problems caused by tourisms, another important issue is the management of wastewater originating from manholes/septic tanks. This type of wastewater is delivered to WWTPs by slurry/vacuum tanks and is usually higher contaminated than municipal wastewater reaching WWTPs via sewerage system. In case the share of manholes/septic tank wastewater is significant in the total WWTP inflow, serious operational and technological problems may arise.

It is noted, however, that the number of septic tanks is decreasing, since they have been replaced with other on-site wastewater treatment systems, mainly biological household wastewater treatment systems

2.3.1. Gdansk-Wschod WWTP

Gdansk-Wschod WWTP is the largest wastewater treatment plant in northern Poland located upon the Baltic Sea. It serves about 571 350 inhabitants, mainly from Gdansk, Sopot and other nearby towns as Pruszcz Gdanski, Zukowo, Kolbudy and Juszkowo. However, the number of tourists visiting Gdansk is about 2 million annually (mainly during summer season). Gdansk has a separated wastewater collection system about 771 km long with 111 pump stations. The designed capacity of WWTP Gdansk-Wschod equals 120 000 m^3/d with a pollutant load corresponding to 840 200 PE (BOD_5).

In 2015 the average wastewater flow equaled 92 958 m^3/d (33 930 000 m^3/year), with a pollutant load of 742 521 PE. Maximal flow values are observed mainly during the summer season (June-August) during the high rain events, while minimal flow occurs in the remaining period. In 2015 the maximal water flow was noted in September with a value of 132 424 m^3/d, while minimal flow was observed in December with a flow of 73 222 m^3/d. The industrial wastewater mainly comes from shipyards, food industry and chemical industry and contribute to 11% of the entire inflow, while inflow from hospital wastewater constitutes <1%. It could be noted that only wastewater from one infectious hospital is disinfected using UV unit. Inflow and outflow characteristic of Gdansk-Wschod WWTP in 2015 is given in Table 2.3.

The Gdansk-Wschod WWTP treatment technology consists of:

- mechanical treatment: wastewater disposal station (for industrial wastewater delivered via slurry tankers - 132 m^3/d), raw wastewater pumping station, mechanical screens with screenings disinfection and odor control, aerated grit chamber with a grease trap, radial primary settling tanks.
- biological treatment: biological reactors working in an anaerobic/anoxic/oxic (A2/O) system (advanced biological nutrients removal), secondary settling tanks with recirculation and excess sludge.
- chemical treatment: PIX dosing system for occasional phosphorus removal.
- sludge treatment: excess sludge from the different processes is digested and finally incinerated.
- WWTP outlet/discharge point: the treated wastewater is discharged into the Gdansk Bay, 2.3 km from the coastline via submarine collector completed with a set of diffusers mounted at a depth of about 8 m (Natura 2000).

Table 2.3. Inflow and outflow characteristic of Gdansk-Wschod WWTP in 2015 (Qav.= 92 958 m^3/d)

Gdansk-Wschod	TSS mg/dm^3	BOD$_5$ mg O$_2$/dm^3	COD mg O$_2$/dm^3	N$_{tot}$ mg N/dm^3	P$_{tot}$ mg P/dm^3
Discharge limits for treated wastewater	35	15	125	10	1
WWTP influent	529	467	986	91	11
WWTP effluent	6	3	32	8	<1
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	208.05	104.03	1109.60	277.40	34.68

Current challenges and plans:

The renovation of Gdansk-Wschod WWTP includes, among other things, modernization of the marine outflow diffuser system, which discharge the treated wastewater into the Gulf of Gdansk. In the long-term the improvement of the nitrogen removal efficiency is planned, however all indicators of treated wastewater are lower than current discharge limits.

Additional information: A serious malfunction of the wastewater pumping station at Olowianka island in May 2018 led to accidental discharge of accumulating raw wastewater to the Motlawa Canal in the amount of Q = 0.7 m^3/s (about 20% of the Motlawa flow), and via the river into Gdansk Bay. The cause of the malfunction of the wastewater plant was probably energy shortage, which increased the sewage level and led to a total breakdown of all four wastewater pumps (two operating and two emergency ones). This draw the attention to the need of both competent technical personnel and local authorities, which should be prepared for crisis situations to properly manage the WWTP.

2.3.2. Gdynia-Debogorze WWTP

Gdynia-Debogorze WWTP is the second largest WWTP facility in northern Poland upon the Baltic Sea serving mainly the population of Gdynia and surrounding smaller towns and communities such as Reda, Rumia and Wejherowo.

The designed capacity of Gdynia-Debogorze WWTP equals 73 000 m^3/d, with an estimated load of 440 000 PE. By 2030 it is expected to be 550 000 PE. In 2015 the average daily inflow rate equaled 55 294 m^3/d (20 182 310 $m^3/year$) and varied from 37 888 m^3/d to 91 324 m^3/d. The hydraulic retention time is about 2 days. Currently about 360 000 inhabitants is served by Gdynia-Debogorze WWTP, while the load expressed in people equivalent in 2015 was equal to 476 000 PE. The industrial wastewater is mostly from food industry, shipyards, pharmaceutical industry and cosmetics industry and their discharges contribute to 10% of the total wastewater inflow. It could be noted that for industrial wastewater onsite pretreatment is often required. Hospital wastewater, which constitutes 0.1% of the entire flow, is discharged directly into the sanitary sewer without disinfection. The yearly average infiltration rate is equal to 5%. Inflow and outflow characteristic of Gdynia-Debogorze WWTP in 2015 is given in Table 2.4.

The Gdynia-Debogorze WWTP treatment technology consists of:

- mechanical treatment: wastewater disposal station (mainly for industrial wastewater delivered via slurry tankers, about 1% of total flow), raw wastewater pumping station, hook screens, grit chamber with a grease trap, radial primary settling tanks.
- biological treatment: biological reactors working in the Bardenpho system with simultaneous denitrification in Carussel system (advanced biological nutrients removal), secondary settling tanks with recirculation and excess sludge (sludge age about 29 days); maintaining the proper technological parameters of the biological processes is ensured by a system of in-situ measurement of several parameters in the reactors (concentration of oxygen, ammonia, nitrate and phosphate) and automatic control of the plant operation.
- chemical treatment: PIX dosing system for occasional phosphorus removal.
- sludge treatment: prior to its methane digestion process, preliminary sludge undergoes gravity thickening, while excessive sludge from bioreactor is thickened on the high-speed centrifuges. Digestion consists of classical anaerobic-mesophilous stage (32÷38 °C) and is followed by the digested sludge dewatering (on chamber presses supported by polyelectrolyte) and incineration. The rejected water from the sludge dewatering is re-circulated downstream, prior to grit chamber

WWTP outlet/discharge point: treated wastewater is discharged into the Bay of Puck (Natura 2000), 2.3 km from the coastline, via submarine collector completed with a set of diffusers mounted at a depth of about 8 m.

Table 2.4. *Gdynia-Debogorze WWTP - inflow and outflow characteristic in 2015 (Qav.= 55 294 m^3/d)*

Gdynia-Debogorze	**TSS mg/dm^3**	**BOD_5 mg O_2/dm^3**	**COD mg O_2/dm^3**	**N_{tot} mg N/dm^3**	**P_{tot} mg P/dm^3**
Discharge limits for treated wastewater	35	15	125	10	1
WWTP influent	488	474	1 090	94.7	11.9
WWTP effluent	0.1	0.1	30.5	7.4	0.64
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	4.01	22.26	647.87	151.47	13.87

Current challenges and plans:

Currently after modernization no technological problems were observed. However, the gradual increase of inert COD in the WWTP results in a proportional increase of COD in the effluent. This unfavorable phenomenon is related to an increased ratio of industrial to municipal wastewater. Reject water from anaerobic digesters is currently directed to the anaerobic reactor. It is planned to treat it separately using an anammox process.

2.3.3 Swarzewo WWTP

The Swarzewo WWTP serves 35 668 inhabitants of Puck, Władysławowo, Swarzewo, Gnieżdżewo, Żelistrzewo, Błądzikowo, Rzucewo, Osłonino, Chłapowo, Chałupy, Mrzezino, Łebcz, Strzelno, Smolno, Celbowo, Połczyno i Zdrad. It is mainly a separated and partly a combined wastewater collection system, with a designed capacity equal to 18 000 m^3/d (180 000 PE).

In 2015 the average daily inflow rate equaled 6 164 m^3/d (149 000 PE), and varied from 2 856 m^3/d to 21 832 m^3/d. A significant difference of average wastewater volume between summer season (June-August) and the remaining period is observed, with Qav.= 8 920 m^3/d and Qav= 5 235 m^3/d, respectively. The maximal and minimal wastewater volume was Qmax = 21 832 m^3/d and Qmin.= 2 856 m^3/d, respectively. These differences are mainly connected with the tourism, however, due to that the wastewater collection system is partly combined and partly separated, the increase of the wastewater inflow at Swarzewo WWTP with occasional hydraulic overload is also to some extent related to the rainwater discharge. To remedy the load variation the Swarzewo WWTP is working in the sequencing batch reactor (SBR) mode. The hydraulic retention time varies from 1 to 4 days. The industrial wastewater is mostly from food, pharmaceutical and cosmetics industry and the discharges contribute to 5% of the total wastewater inflow. For industrial wastewater onsite pretreatment is often required. Hospital wastewater, which constitutes <1% of the entire flow, is discharge directly into the sanitary sewer without disinfection. Yearly average infiltration rate is equal 28%. Inflow and outflow characteristic of Swarzewo WWTP in 2015 is given in Table 2.5.

The Swarzewo WWTP treatment technology consists of:

- mechanical treatment: wastewater disposal station (mainly for manholes/septic tanks wastewater delivered via slurry tankers, about 3.5% of total flow), retention tank, raw wastewater pumping station, screens with combined grit trap and grease separation.
- biological treatment: six sequencing batch reactors (with sludge age about 63 days) are operated in a conventional nitrification-denitrification process, with methanol used as an external source of organic carbon, treated wastewater is directed to two stabilization ponds.
- chemical treatment: precipitation of phosphorus is supported with PIX.
- sewage sludge treatment: primary and excessive sludge from the bioreactor is thickened then co-digested (fermentation of sewage sludge together with organic waste) in a classical anaerobic-mesophilic regime (38÷40 °C). The rejected water is recirculated to the wastewater stream after the mechanical part. The digested sludge is dewatered (on high-speed centrifuges), next composted together with the green wastes and finally used in agriculture.
- WWTP outlet/discharge point: treated wastewater is discharged into the Baltic see about 1.4 km from the coastline, via submarine collector completed with a set of diffusers.

Table 2.5. Inflow and outflow characteristic of Swarzewo WWTP in 2015 (Qav. = 6 164 m^3/d).

Swarzewo	TSS mg/dm^3	BOD_5 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits for treated wastewater	35	15	125	10	1
WWTP influent	814.0	774.6	1676.4	131.5	19.4
WWTP effluent	8.4	5.7	38.6	18.0	2.2
Pollution load discharged into the receiver [t/year]					
via treated wastewater	17.4	12.1	85.0	44.5	5.2

Current challenges and plans:

Tourism growth has significantly increased the pressure on both the existing infrastructure of wastewater services and water supply systems. Swarzewo WWTP was overloaded during the summer season, until modernization in 2015, when its hydraulic capacity increased up to 18 000 m^3/d. The irregularity of wastewater inflow is reflected in the hydraulic retention time, which currently varies from 1 day in the summer season to 4 days in the remaining period. But the overload problems at Swarzewo WWTP are also observed during the rain events, due to the partly combined, partly separated wastewater collection system. As a result the solids wash-out from the settling tanks of the activated sludge process. Thus, to avoid contamination of the receiver at the Swarzewo WWTP, the treated wastewater is directed to the stabilization ponds before discharge to the Baltic Sea. Importantly during the solid wash-out, the available active biomass is decreasing, which adversely influence the treatment capacity.

2.3.4 Jastrzebia Gora WWTP

The Jastrzebia Gora WWTP serves Jastrzębia Góra, Rozewie, Tupadly, Ostrowo, Karwia, Mieroszyno, Kaczyniec and Czarny Młyn. It works with conventional treatment based of active sludge with increased nutrients removal. The designed capacity of WWTP equals 7 305 m^3/d and a pollutant load corresponding to 62 000 PE.

In 2015 the average daily inflow rate equaled 1 678 m^3/d, and ranged from 529 m^3/d to 5 592 m^3/d, while the average pollutant load to the WWTP corresponded to 12 540 PE. Inflow and outflow characteristic of Jastrzebia-Gora WWTP in 2015 is given in Table 2.6.

The Jastrzebia Gora WWTP treatment technology consists of:

- mechanical treatment: wastewater disposal station (mainly for manholes/septic tanks wastewater delivered via slurry tankers), retention tank, raw wastewater pumping station, screens with combined grit trap and grease separation.
- biological treatment: biological treatment of wastewater takes place in a five-stage (modified) Bardenpho process, which requires the use of multiple tank zones operated in anaerobic (pre-denitrification), anoxic (dephosphatation), anaerobic (denitrification), and aerobic (nitrification) modes, followed by radial secondary settling tanks; treated wastewater undergo UV disinfection prior to discharge to the receiver.

- sewage sludge treatment: the excessive sludge is directed to the aerobic stabilization; the sludge dewatering system is equipped with two belt press and polyelectrolyte preparation and dosing systems; after the press, the sludge undergoes hygienisation with lime (CaO); rejected water is recirculated to the biological reactors.
- WWTP outlet/discharge point: treated wastewater is directed to the Czarna Wda river with a direct outflow to the Baltic Sea.

Table 2.6. *Inflow and outflow characteristic of WWTP Jastrzebia Gora in 2015 (Qav. = 1 678 m^3/d).*

Jastrzebia Gora	**TSS mg/dm^3**	**BOD$_5$ mg O$_2$/dm^3**	**COD mg O$_2$/dm^3**	**N$_{tot}$ mg N/dm^3**	**P$_{tot}$ mg P/dm^3**
Discharge limits for treated wastewater	35	15	125	15	2
Discharge limits for treated wastewater October - April	*35*	*25*	*125*	-	-
WWTP influent	464.7	473	1047	90.5	10.8
WWTP effluent	4.7	2.3	31.1	6.3	0.4
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	2.88	1.41	19.05	3.86	0.24

Current challenges and plans

The last modernization was carried out in 2012, but currently, due to growth in tourism mainly in the summer season, the construction of a fourth bioreactor and a secondary retention tank as well as an extension of the sewage sludge treatment by adding an additional dewatering press are planned.

2.4 Prospects and challenges for M-WWTPs in Poland

Among current challenges in the WWTP sector in the model area the following points can be listed: need for proper handling of the numerous septic tanks in rural areas; a seasonal (touristic) changes of wastewater inflow, which primarily influence the small WWTPs efficiency; need for competent technical personnel to properly handle the small WWTPs; need for knowledge transfer and education and training of local authorities responsible for the wastewater sector and environmental protection; upgrading of small plants to face the new requirements connected with nitrogen removal; sludge treatment and proper management of rejected water originating from sewage sludge management (physical, chemical and biological treatment) is needed; industrial load that can be discharged and effectively treated, without compromising the treatment capability of a WWTP should be properly estimated. To undertake the actions listed above, access to funds for public wastewater systems is needed, especially in rural areas.

A detailed analysis of the four M-WWTPs located in the model area led to the following conclusions.

At large WWTPs as Gdansk-Wschod and Gdynia-Debogorze currently no technological problems were observed. However, a gradual increase of the inert COD in the incoming wastewater is observed, which results in an increase of the COD in effluents. Special attention is also given to the nitrogen-rich reject water from anaerobic digesters, which is currently redirected to the main treatment line. At Gdynia-Debogorze WWTP it is planned to treat this water separately using an anammox process. The above investment will be implemented as part of the modernization of the sewage sludge treatment line.

An increasing number of people served from June to September with a peak in July and August needs attention, especially at Swarzewo WWTP and Jastrzebia Gora WWTP. In Swarzewo WWTP lately the new treatment line was added to handle the increasing amount of wastewater in the touristic season but still the plant is occasionally overloaded. In Jastrzebia Gora WWTP, currently an extension of the sewage sludge treatment capacity is underway by adding a fourth bioreactor and a secondary retention tank as well as the additional dewatering press. Additionally, Swarzewo WWTP and Jastrzebia Gora WWTP is recieving poor quality wastewater, which is collected from the septic tanks and delivered to both WWTPs via special transports. This kind of wastewater is usually highly condensed, and should be gradually added to the main treatment line due to the high pollution load. There is still a need for competent technical personnel to properly handle the WWTPs and local authorities to wisely manage and invest in the wastewater sector as well as to be prepared for emergency crises. In the studied area no investments regarding the removal of micropollutants are planned in the near future.

3. Survey on wastewater treatment in the model area of Kristianstad municipality, Skåne County in Sweden (2016)

3.1 Kristianstad municipality, Skåne County – general information

Skåne County (Swedish: Skåne län), is one out of 21 counties in Sweden, and is the southmost region in Sweden surrounded by sea on three sides as shown in Figure 3.1.

Figure 3.1. Overview of geographic position of Skåne County (Sweden) in relation to the Baltic Sea and the surrounding partner countries of the MORPHEUS project. In the map the 4 largest cities of Skåne are shown together with their ranking in size as compared to all other Swedish cities. For details see text.

Skåne covers an area of 11 027 km^2 which is only 2.5% of the total area of Sweden (447 419 km^2). According to Statistics Sweden (Statistiska Centralbyrån – SCB) the total population of Skåne 2015-12-31 was 1 303 627 inhabitants which is 13.2% of the total Swedish population (9 851 017 inh. on the same date). Skåne is consequently a densely populated area of Sweden with some relatively large cities, from a Swedish perspective, as indicated in Figure 3.1. This includes Malmö 301 706 inh. (rank 3), Helsingborg 104 205 inh. (rank 9), Lund 87 244 inh. (rank 12) and Kristianstad 39 762 inh. (rank 29). These city data only include the central cities, while the entire municipalities of Malmö, Helsingborg, Lund and Kristianstad have populations of 322 574, 137 909, 116 834 and 82 510, respectively (2015-12-31). Skåne is famous for its agriculture, long coastline and beautiful landscape. Thus, ecosystem services such as recreation in nature, sport, fishing, as well as local food production, are essential for an economical sustainable region. Skåne also have one of Sweden's largest and oldest universities, Lund University from 1666. In Lund is presently also the European Spallation Source (ESS) under construction, which is a European research infrastructure consortium, and multi-disciplinary research facility that will host one of the world's most powerful neutron sources. The ambition of Skåne County is to be an international leader in environmental and social sustainability. Therefore, sectors related to clean technology, including transport, energy, wastewater and the solid waste sector, is here one of the most dynamic in Northern Europe.

The total volume of water consumption in Skåne is reported every fifth year by Statistics Sweden. Data for the years 2005, 2010 and 2015 are shown in Figure 3.2.

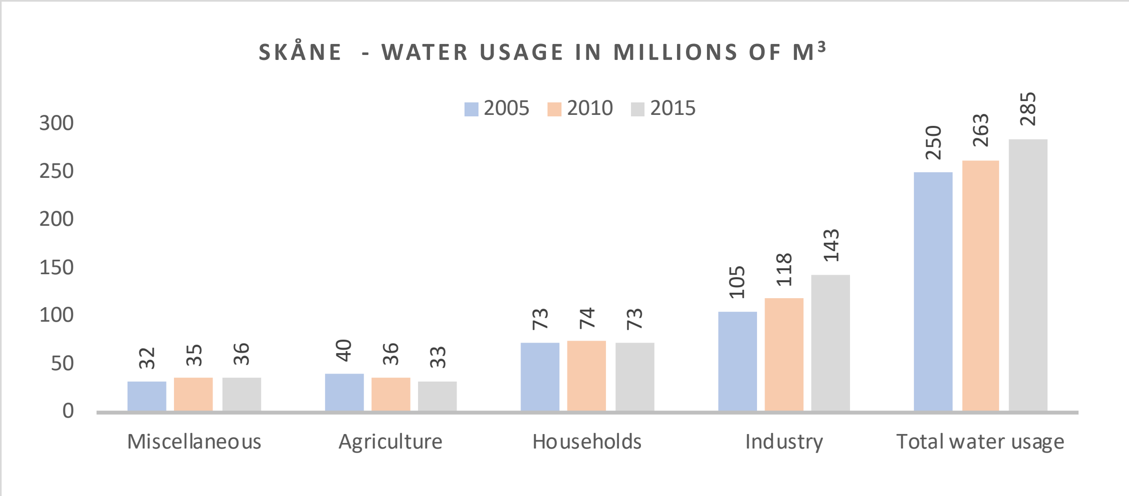

Figure 3.2. *Water usage in millions of cubic meters in Skåne 2005, 2010 and 2015.*

The total water usage in Skåne 2015 was 285 millions of m^3, which was an increase by 14% since 2005. This increase was mainly caused by increased industrial use, while household usage was basically constant. By simple calculations the water usage in Skåne 2015 can also be compared to the overall Swedish usage expressed in cubic meter per capita to identify similarities and/or differences between Skåne and Sweden in general. The results are shown in Figure 3.3.

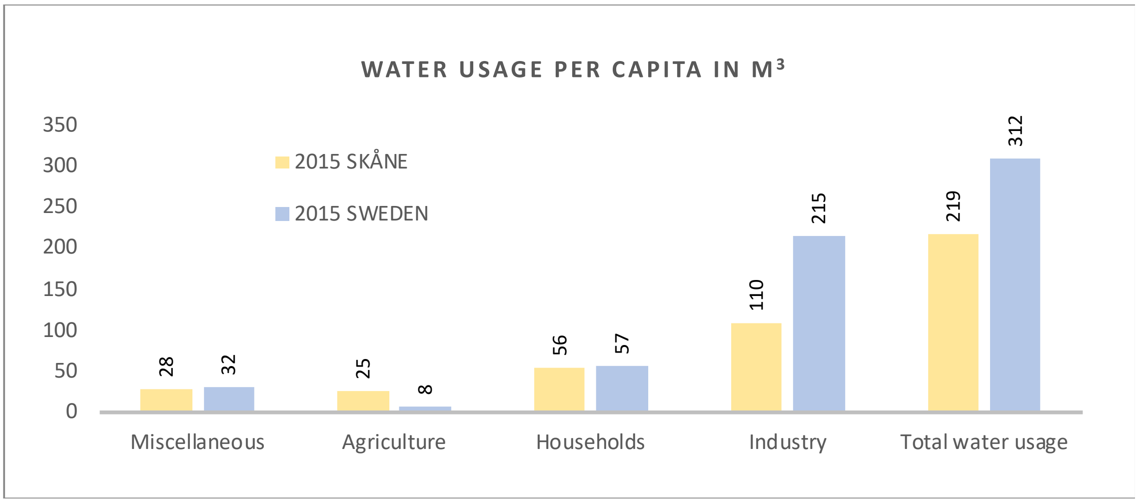

Figure 3.3. *Water usage in cubic meters per capita in Skåne and Sweden in 2015.*

From Figure 3.3. it can be seen that the total water usage per capita is lower in Skåne with a value of 219 m^3, than in Sweden in general using 312 m^3. The main difference is a larger usage of water in the industrial sector. Skåne on the other hand has a much higher usage of water in the agricultural sector than the rest of Sweden with values of 25 m^3 and 8 m^3, respectively. This reflects the fact that Skåne is one of Sweden's most intensive agricultural areas due to very fertile soils. Looking at usage of water in households, Skåne and Sweden have nearly identical usage of 56 m^3 and 57 m^3 per capita, respectively. Based on official data the relative distribution of water usage in Skåne and Sweden can also be calculated and visualized for the year 2005, 2010 and 2015 as shown in Figure 3.4.

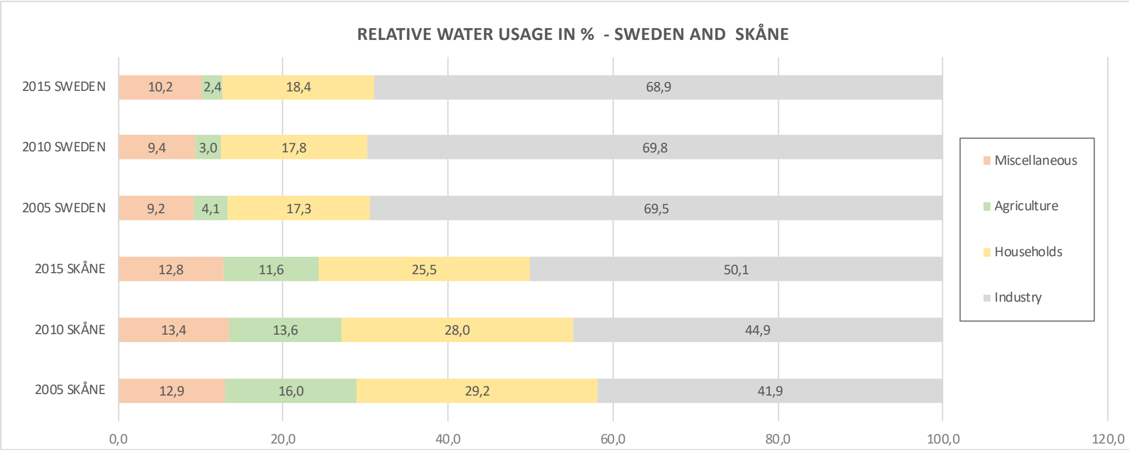

Figure 3.4. *Relative water usage expressed as percent in Skåne and Sweden in 2005, 2010 and 2015.*

Figure 3.4. clearly shows the difference in water usage between Skåne and Sweden in general, with a higher usage of water (in percent) in the industrial sector in Sweden, and a higher usage of water in the agricultural sector in Skåne. From a Skåne County perspective the high demands on water usage in the agricultural sector is an increasing concern as draught periods may increase as a consequence of a changing climate. The summer of 2018 was very severe for farmers in Skåne as the harvest was much lower than normal, and the availability of forage on grass for cattle was low. Households were in some cases also prohibited from using water in private gardens due to lack of water supplies. Considering that more than 25% of the water usage in Skåne is households (Figure 3.4) there may be opportunities for a more intensive reuse of water from this sector.

3.2 Wastewater management in Skåne County and Kristianstad municipality

Region Skåne is divided into 33 different municipalities. In the MORPHEUS project, Kristianstad municipality was the main focus including 3 model WWTPs; Kristianstad WWTP, Tollarp WWTP and Degeberga WWTP. In 2016 the number of actual PE for these three WWTPs were 118 000, 4 790 and 950, respectively. The model WWTPs will be described in more detail below, while their geographical positions within the borders of Kristianstad municipality are shown in Figure 3.5.

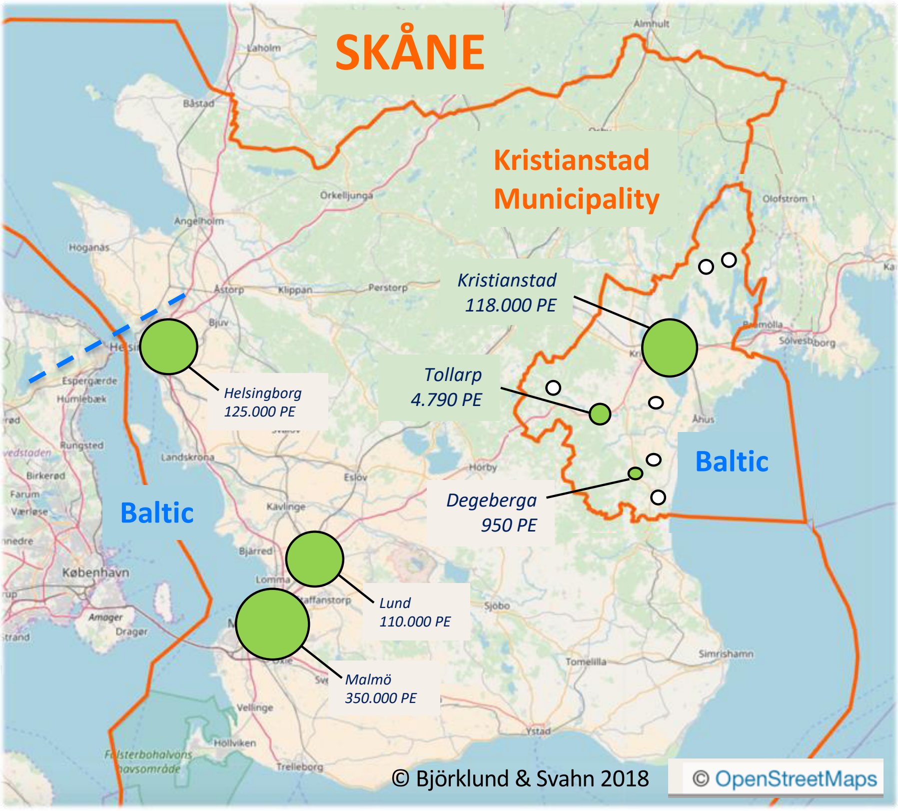

***Figure 3.5.** The borders of Skåne and Kristianstad municipality showing the position of the 3 model WWTPs; Kristianstad WWTP, Tollarp WWTP and Degeberga WWTP and their number of PEs (2016). White circles within Kristianstad municipality borders represent 6 additional WWTPs with <2000 PE. Indicated are also three additional major WWTPs in Skåne for the cities of Malmö, Helsingborg and Lund.*

From Figure 3.5 it can also be seen that Kristianstad municipality covers a relatively large area of 1 250 m^2 and it ranks as the largest municipality in Skåne corresponding to 11%. Indicated in Figure 3.5 are the three additional major WWTPs in Skåne treating wastewater from the three largest cities of Skåne; Malmö, Helsingborg and Lund.

The total number of WWTPs in Skåne > 2000 PE in 2016 was 43 according to Statistics Sweden. These represented in total 1 260 888 PE. The official data on WWTPs only covered WWTPs with >2000 persons connected, or with a BOD_7 load of at least 2000 PE, as these require a permission (it could be noted that according to official data all these WWTPs in Skåne have installed some type of biological-chemical treatment). Corresponding Figureures for all of Sweden was 413 WWTPs with >2000 PE, representing in toal 8 633 145 PE. The 3 model WWTPs within Kristianstad municipality cover a wide range of sizes (950-118 000 PE). Kristianstad WWTP is one of Skånes largest WWTPs, while Tollarp WWTP is an example of a small sized village, still exceeding the limit of 2000 PE. Finally, Degeberga is a very small WWTP not covered in the official data. The exact number of WWTPs in Skåne with <2000 PE could not be identified in any official data or reports, but as shown below they are most likely around 50. Kristianstad municipality has 6 additional small WWTPs with <2000 PE in the villages of Arkelstorp, Vittskövle, Maglehem, Gärds Köpinge, Vånga and Rickarum.

Their geographical positions are indicated with white circles in Figure 3.5 while their size in relation to other WWTPs in Skåne is shown in Figure 3.6 below. Overall this means that

Kristianstad Municipality has a total of 9 WWTPs. However, a vast majority of all wastewater is still treated in Kristianstad WWTP. The reason for this is that in most urbanized areas of Kristianstad municipality all households are connected to this central wastewater treatment plants via pipes.

The total volume of wastewater in Sweden 2016 was 1 078 652 000 m^3 according to Statistics Sweden. However, no data were identified on the total volume of wastewater in Region Skåne. A preliminary figure was calculated based on information on treated wastewater found on websites of the municipalities in Skåne where environmental reports on wastewater treatment in many cases are displayed and can be downloaded. Summing up the individual volume of all identified wastewater treatment plants gives an estimated figure of 152 886 856 m^3 of treated wastewater in Skåne. This represents 14.2% of the total volume of wastewater in Sweden and corresponds relatively well with the fact that the population of Skåne is 13.2% of the Swedish population. The collected data of wastewater volumes in the different WWTPs also gives an illustrative overview of the distribution of WWTPs in Skåne and how the size of the 3 model WWTPs in Kristianstad, Tollarp and Degeberga relate to other WWTPs as shown in Figure 3.6. Based on the data in Figure 3.6, the total number of WWTPs in Skåne can be estimated to be more than 90. As discussed above the number of WWTPs with a size >2000 PE or a BOD_7 corresponding to >2000 PE are 43. From this it seems that the number of WWTPs with a size <2000 PE should be around 50.

Looking closer at the size of the 9 WWTPs in Kristianstad municipality in terms of treated volume of wastewater it can also be seen that their wide distribution relatively well represents the great diversity of all WWTPs in Skåne (Figure 3.6). Kristianstad WWTP (1) stands out, as it is one of the largest WWTPs in Skåne. Tollarp WWTP (2) has a size representing many of the smaller villages outside the larger cities, where Tollarp has a population of ca 3 500 inhabitants. Degeberga WWTP (5) has a size representing even smaller villages, with a population of less than 1 500 inhabitants. For comparison Arkelstorp (3), Vittskövle (4), Maglehem (6) and Gärds Köpinge (7) have populations of 801, 237, 151, and 924 inhabitants, respectively. The relatively low number of inhabitants at Maglehem in relation to the high water volume is a consequence of a very high amount of intruding water in the pipes. Finally, Vånga (8) and Rickarum (9) are very small country-side WWTPs treating only around 10 000 m^3 wastewater yearly.

A final note is that Skåne faces an environmental load of phosphorus and nitrogen released from small-scale/domestic systems. In these cases, infiltration and drain field systems are the most commonly used. Their removal efficiency of nutrients is limited, thus small-scale/domestic systems may have an impact on lakes, rivers, and coastal waters. This situation changes continuously, especially in areas of new housing developments. Smaller plants are then replaced with pumping stations that transfer wastewater to larger, more advanced wastewater treatment plants, something that has been done in for example Kristianstad municipality (see Figure 3.8).

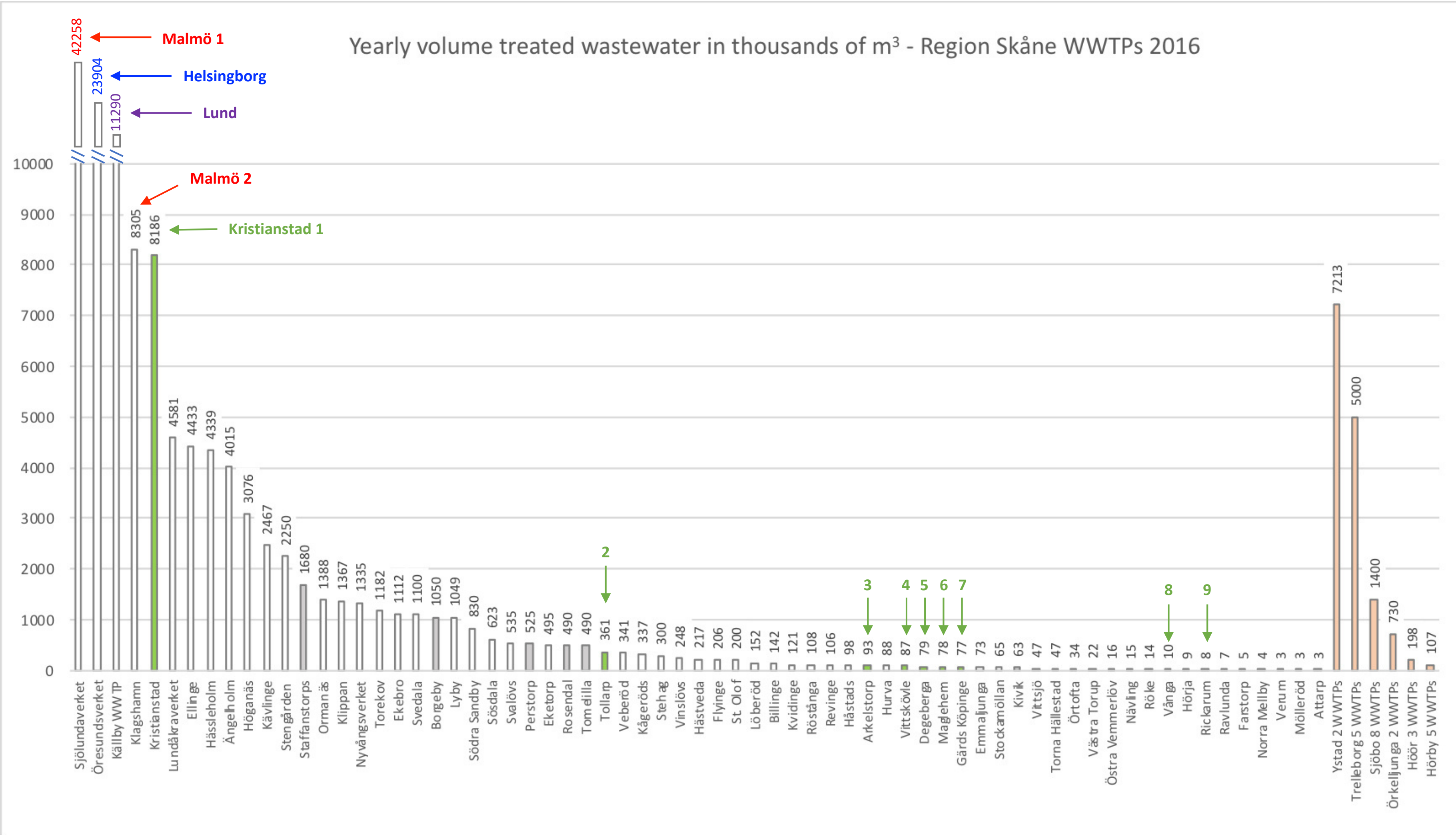

Figure 3.6. *Yearly volume treated wastewater in WWTPs in Skåne 2016. WWTPs in Malmö, Helsingborg and Lund are all above 10 000 000 m^3 and out of scale. The 9 WWTPs in Kristianstad Municipality are indicated with green bars, arrows and numbers. WWTPs shown with grey bars are estimated volumes due to lack of identified official data. In the right of the figure in orange bars are municipalities which only gave the total volume of wastewater treated in all WWTPs in that specific municipality*

3.3 Model wastewater treatment plants (M-WWTPs) in Kristianstad municipality, Skåne County

In Kristianstad municipality 3 model wastewater treatment plants WWTPs were chosen for the survey of existing technology as described above: Kristianstad WWTP, Tollarp WWTP and Degeberga WWTP (Figure 3.7).

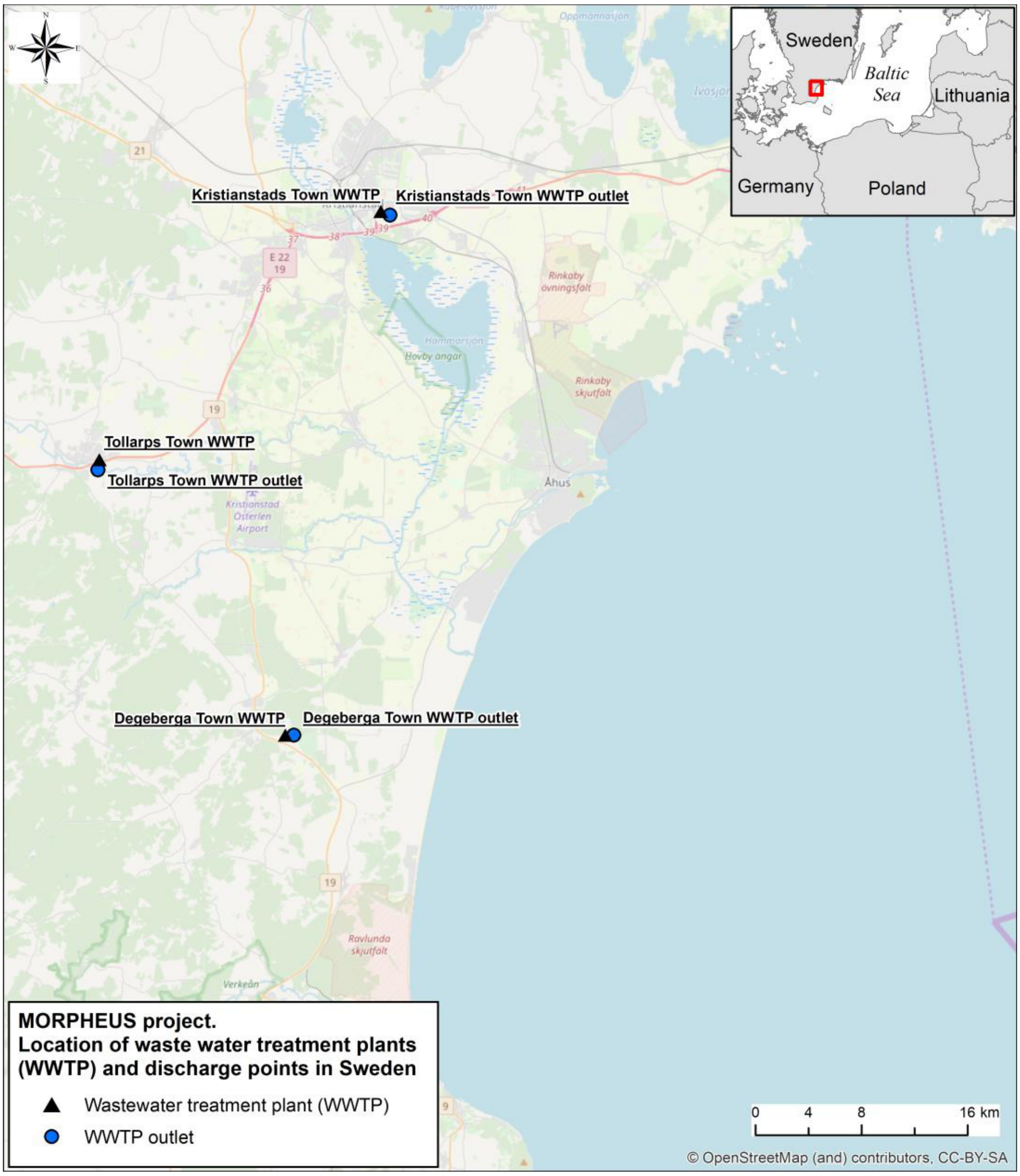

Figure 3.7. *Localization of M-WWTPs and their discharge points in the model area of Kristianstad Municipality, Skåne County, Sweden.*

3.3.1 Kristianstad WWTP

Kristianstad WWTP (Centrala Reningsverket i Kristianstad – CRV) is serving the population of Kristianstad City (39 762 inh. 2015-12-31) and 17 smaller villages, which are connected to the WWTP. A very schematic overview of how these smaller villages are connected is shown in Figure 3.8. The wastewater collection system is about 485 km long with 120 pump stations and is in general separated from the rain water systems. The number of inhabitants connected to the WWTP equaled 52 000 both 2016 and 2017. In addition to this around 28 000 seasonal visitors and tourist are connected to the system.

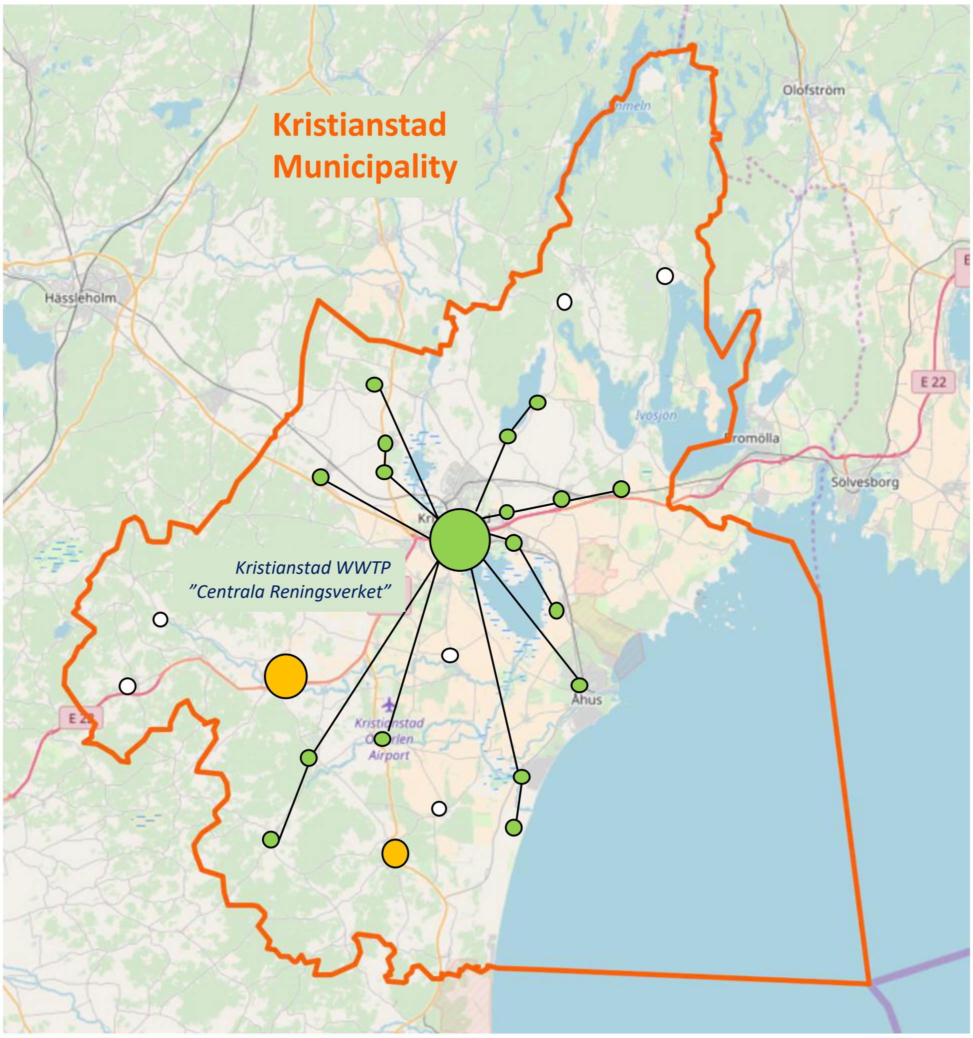

Figure 3.8. *Kristianstad municipality - a schematic overview of Kristianstad WWTP (Centrala Reningsverket – CRV) and the surrounding villages connected via a waste water collection system consisting of pipes and pumps. Indicated with orange circles are Tollarp WWTP and Degeberga WWTP, while white circles represent 6 additional WWTPs with <2000 PE.*

The current total pollutant load at Kristianstad WWTP corresponded to 118 000 PE in 2016 and 111 000 PE in 2017 (BOD_7 8 500 kg/d, P-tot 180 kg/d, N-tot 1 100 kg/d), while the designed and maximum allowed capacity equaled 205 000 PE (BOD_7 14 500 kg/d, P-tot 330 kg/d, N-tot 1 850 kg/d). The industrial wastewater contribution is substantial and comes from The Absolut Company (spirits), Scan (slaughterhouse), Skånemejerier (dairy) and Lyckeby Starch (starch and protein). Together these contributed to 64 000 PE in 2016 (54%) and 69 000 PE in 2017 (62%).

The average actual wastewater flow equaled 22 427 m^3/d (8 186 000 m^3/year) in 2016 and 23 000 m^3/d (8 395 000 m^3/year) in 2017. Minimal/maximal flow values observed in 2017 equaled 18 000 m^3/d and 38 500 m^3/d, respectively. Inflow and outflow characteristic of Kristianstad WWTP in 2016 is given in Table 3.1.

The Kristianstad WWTP treatment technology consists of mechanical, biological and chemical treatment with the following components:

- mechanical treatment (in 2 parallel lines): mechanical *screen*s and aerated sand traps. Then the waste water is directed to the pre-sedimentation lines with 3 pre-sedimentation basins (total of 6 basins).
- biological treatment: in the biological step in general an anoxic phase (pre-denitrification supported by external carbon source – Brenntaplus) is followed by an aerobic phase, but the wastewater stream is divided in two parallel lines named: N and E.
    - N: the wastewater is pumped to a mixing channel where it is mixed with returning sludge. It is thereafter pumped to the activated sludge basins followed by pumping to a pre-sedimentation basin prior to the chemical treatment step.
    - E: the wastewater is pumped into the activated sludge basins and a process called Krauss System. After this step the water is pumped to the same pre-sedimentation basin as those used for N above, prior to the chemical treatment step.
- excess sludge is passed on to the final sludge treatment process.
- chemical treatment: PIX (Ferric chloride) dosing system is used for phosphorus removal in four parallel precipitation lines. Each line has three serial flocculation basins followed by a sedimentation basins and open sand filters for a final polish.
- sludge treatment: sludge from the different processes (pre-sedimentation, biological treatment and chemical treatment) ends up in a sludge thickener to reach a dry matter content of 1.5%. In a second step the sludge is further dewatered to a dry mater content of 3.5%. Thereafter the sludge is transported to anaerobic digestion and stabilization. Digested sewage sludge is degassed and stored under stirring conditions to be further thickened. Final dewatering of sludge is done by adding a polymer (Zetag 8160/Zetag 8167) followed by centrifugation. The water phase is transported back to the inlet of the WWTP in the aerated sand trap. Dried sludge is stored in temporary dry silos and later used as fertilizer in agriculture.

- WWTP outlet/discharge point: the final treated wastewater is passed on to a 1 500 m long ditch, which ends in Hammarsjön Lake (Natura 2000 area according to the Habitats Directive), which is part of Helge Å River. Helge Å River is a direct tributary of the Baltic Sea, with the river ending in the of Hanöbukten Bay (Baltic Sea) which is regarded as a Natura 2000 (Habitats Directive). The area is covered by more than 8000 ha of valuable wetland, protected according to The Ramsar Convention on Wetlands. The lower part of Helge Å River including Hammarsjön Lake is thereby a unique wetland and was given the status of a UNESCO Biosphere Reserve in 2005, with the name "Vattenriket". The area holds a great variety of species of which many are red listed.

Table 3.1. *Inflow and outflow characteristic for Kristianstad WWTP in 2016 (Qav.= 22 427 m³/d).*

Kristianstad WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Raw wastewater	nt	369.2	881.7	48.7	8.34
Treated wastewater	nt	1.9	28.3	6.0	0.07
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	nt	16.1	232.0	49.1	0.565

nt – not tested

Current challenges and plans:

Kristianstad WWTP is presently in a phase of major changes according to the official information from Kristianstad Municipality. In summary Kristianstad's central treatment plant was built in 1956 and thoroughly renovated in 1976. Additional renovation occurred in 1992 when it reached the capacity the plant has today. Kristianstad municipality further informs that the plant can handle sewage from a population equivalent to 160 000 people (205 000 according to official reports), which may sound as a good margin for cleaning capacity, given that the municipality has 83 000 inhabitants. However, Kristianstad has several major food industries (see text above) that also send their sewage to the central sewage treatment plant. In order to ensure that Kristianstad can meet predicted growth, and thus the future needs of sewage treatment, the central sewage treatment plant will be rebuilt and expanded to a capacity equivalent to 260 000 people. Three of the five purification steps will be expanded in an initial step where the project is expected to enter the early construction phases in 2019. After personal communication with personnel at Kristianstad WWTP this include a new inlet of wastewater, new screens and new biological and chemical treatment steps. The process is expected to take around 4 years. Additional changes may come at a later stage including how to remove pharmaceuticals and other micropollutants with advanced treatment technologies, which is part of a more long-term goal.

3.3.2 Tollarp WWTP

Tollarp WWTP (Tollarp Avloppsreningsverk) is serving mainly the population of Tollarp (3 404 inh. 2015-12-31) and one major food production industry (Orkla Foods Sverige). The wastewater collection system, about 40 km long and with 9 pump stations, is in general separated from the rain water systems. The number of inhabitants connected to WWTP equaled 3 000 in 2016 and 3 400 in 2017. No information on seasonal visitors or tourist were found but is likely limited. The current total pollutant load corresponded to 4 790 PE in 2016 and 6 000 PE in 2017, while the designed and maximum allowed capacity equaled 9 000 PE (BOD_7 900 kg/d, P-tot 30 kg/d, N-tot 100 kg/d). The industrial wastewater is mostly from the food industry which contributed to around 3 900 PE.

The average actual wastewater flow volume equaled 989 m^3/d (361 000 m^3/year) in 2016 and 1 063 m^3/d (388 000 m^3/year) in 2017. Any minimal/maximal flow values could be identified for Tollarp WWTP. Inflow and outflow characteristic of Tollarp WWTP in 2016 is given in Table 3.2.

The Tollarp WWTP treatment technology consists of mechanical, biological and chemical treatment with the following components:

- mechanical treatment: mechanical *screen*s and grit chamber, then the waste water is pumped to an activated sludge process.
- biological treatment: aerated contact basins and activation basins followed by sedimentation tank; in the biological treatment the wastewater is mixed with sludge from both the activation process itself and sludge from the chemical treatment step.
- chemical treatment: PIX (ferrous chloride) dosing system is used for phosphorus removal; flocculation process is aerated and followed by a final sedimentation basin. The sludge from the chemical treatment process is returned to the activation basin step.
- WWTP outlet/discharge point: treated wastewater is discharged by gravity into the Vramsån River (pumped only when there is a high water level in the river). The average flow of Vramsån River was 4.8 m^3/s in 2017, but the river has a very winding watercourse and regularly floods the surrounding fields. Vramsån River contains a number of rare species and is one of Europes finest rivers for a number of mussels. Vramsån river is part of the UNESCO Biosphere Reserve "*Vattenriket*" and is a Natura 2000 Site.

***Table 3.2.** Inflow and outflow characteristic for Tollarp WWTP in 2016 (Qav.= 989 m^3/d).*

Tollarp WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Raw wastewater	nt	349.0	739.6	28.5	3.88
Treated wastewater	nt	3.21	20.5	5.5	0.10
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	nt	1.16	7.4	2.0	0.037

nt – not tested

Current challenges and plans:

No immediate changes are foreseen or planned at Tollarp WWTP according to personnel responsible for the daily maintenance and coordination of the treatment plant.

3.3.3 Degeberga WWTP

Degeberga WWTP (Degeberga Avloppsreningsverk) is serving the population of Degeberga (1 328 inh. 2015-12-31). No major industry is connected to the WWTP. The current total pollutant load corresponded to 950 PE in 2016, while the designed capacity equals 2 000 PE (BOD_7 200 kg/d). The wastewater is originating only from households. No information on seasonal visitors or tourist were found and is therefore not known. The average actual wastewater flow volume equaled 216 m^3/d (79 000 m^3/year) in 2016. No minimal/maximal flow values could be identified for Degeberga WWTP. Inflow and outflow characteristic of Degeberga WWTP in 2016 is given in Table 3.3).

The Degeberga WWTP treatment technology consists of mechanical, biological and chemical treatment with the following components:

- mechanical treatment: mechanical screens and aerated grit chamber, then the waste water is pumped to an activated sludge process.
- biological treatment: traditional activated sludge process with denitrification basin, where the wastewater is mixed with sludge from the chemical treatment step, followed by aerated basin (nitrification step). In this step the water is mixed with sludge from the clarifier (sedimentation step right after the biological treatment).
- chemical treatment: PIX (ferrous chloride) dosing system is used for phosphorus removal; flocculation process is followed by sedimentation basins and the passed further on to an open sand filter for a final polish. The sludge from chemical treatment process is returned to the denitrification step.
- sludge treatment: the excess sludge from the sedimentation step after the biological treatment step is stored in a sludge storage magazine, and thereafter pumped manually out into reed beds. In the reed beds the sludge is going through dewatering, mineralisation and hygienisation processes.
- WWTP outlet/discharge point: treated wastewater is discharged directly into the Segesholmsån River (average flow rate of 0.8 m^3/s in 2017). It is one of the best-preserved rivers in Region Skåne, inhabited by many sensitive species e.g. red listed insects, trout and rare species of caddisflies.

***Table 3.3**. Inflow and outflow characteristic for Degeberga WWTP in 2016 (Qav.= 216 m^3/d).*

Degeberga WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Raw wastewater	nt	321.5	799	62.3	8.28
Treated wastewater	nt	1.5	15	13.2	0.16
Pollution load discharged into the receiver [t/year]					
Via treated wastewater	nt	0.119	1.186	1.039	0.013

nt – not tested

Current challenges and plans:

No immediate changes are foreseen or planned at Degeberga WWTP according to personnel responsible for the daily maintenance and coordination of the treatment plant. Noteworthy is however that an application for governmental investment funding was handed in to the Swedish Environmental Protection Agency by Kristianstad Municipality in September 2018 for upgrading Degeberga WWTP with advanced treatment of pharmaceuticals using activated carbon.

3.4 Prospects and challenges for M-WWTPs in Region Skåne and Sweden

It has been shown in various studies that by increasing the size of WWTPs the costs for treating a cubic meter of waste water can be decreased. Many of the smaller WWTPs might therefore be replaced with pumping stations and thereafter the wastewater can be transferred via pipes to larger, more advanced WWTPs. Kristianstad municipality is such an example that to a large extent has centralized the wastewater treatment to the major treatment plant in Kristianstad City. Additionally, in order to ensure that Kristianstad WWTP will meet the future needs of sewage treatment, the central plant will be rebuilt and expanded in capacity from 205 000 PE to 260 000 PE. The timeline for reconstruction is around 4-5 years. Similar plans are being made also in the southwest of Region Skåne were there are plans of closing down the large WWTP in Lund (110 000 PE) and pump the water ca. 20 km to a new even larger WWTP that is planned to be built in Malmö with a total capacity of 450 000 PE. However, such a major change is expected to take 10 years, with the new WWTP being ready 2028.

In Kristianstad Municipality, advanced treatment of micropollutants using activated carbon is planned at Degeberga WWTP. Results from Degeberga might be useful at a later stage if Kristianstad WWTP is to be equipped by advanced treatment. Implementation of such technology at large scale will take several years before becoming reality though.

In Skåne as well as in the rest of Sweden a substantial environmental release of nitrogen, phosphorus and micropollutants is also occurring via onsite sewage treatment facilities, a release that may reach groundwater and or receiving water bodies. In Sweden around 1million people (10% of the population) are connected to such facilities and there is a great challenge to upgrade such systems with improved technology.

4. Survey on wastewater treatment in the model area of Klaipėda County in Lithuania (2015)

4.1 Klaipėda County – general information

Klaipėda County (Lithuanian: *Klaipėdos apskritis*) is one of ten counties in Lithuania. It lies in the west of the country and is the only county to have a coastline. Its capital is Klaipėda. On 1st July 2010, the county administration was abolished, and since that date, Klaipėda County remains as the territorial and statistical unit (Figure 4.1).

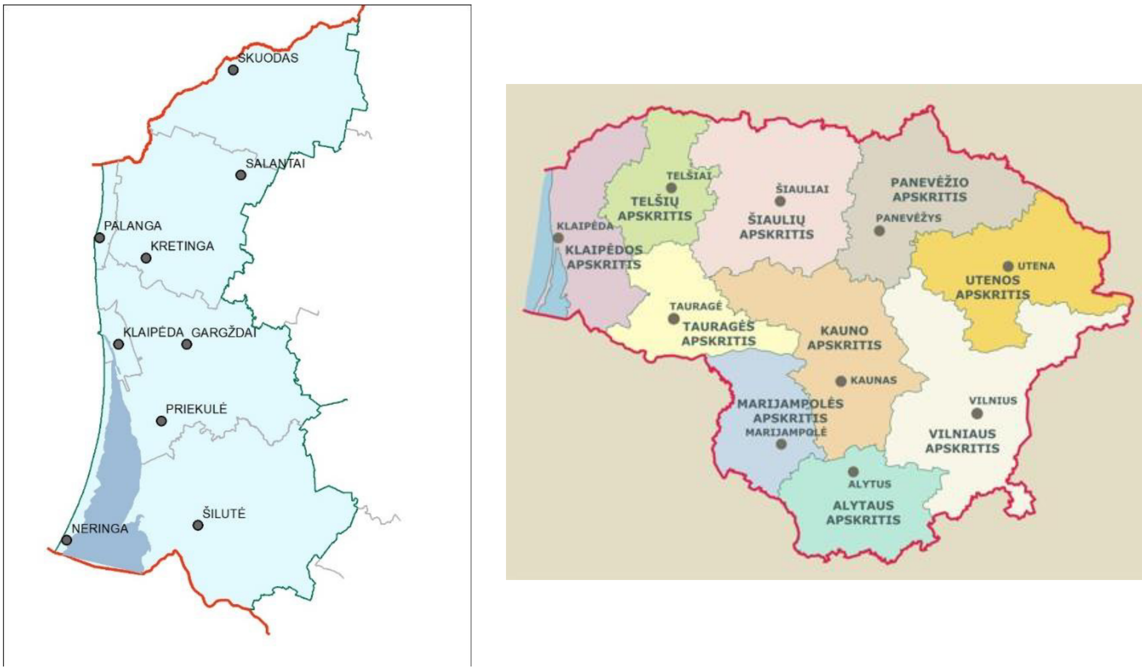

***Figure 4.1** Administrative division of the Lithuania and geographical location of Klaipeda County - Lithuanian model area.*

The total area is 5 209 km^2 (8% of the area of Lithuania) with a population of 320 507 in 2017 (11.3% of the population of Lithuania). Klaipeda County is divided into 7 different municipalities: Klaipėda City Municipality, Klaipėda District Municipality, Kretinga District Municipality, Neringa Municipality, Palanga Town Municipality, Šilutė District Municipality and Skuodas District Municipality. In the MORPHEUS project, 4 model WWTPs was selected in 4 municipalities administrative centres: Klaipėda city, Palanga, Kretinga towns and Nida settlement - the biggest settlement and an administrative centre of Meringa municipality. The whole of the Lithuanian Coastal Rivers Basin is situated in the Coastal Lowland (*Pajūrio žemuma*). The catchment is represented mainly by small watercourses draining straight into the Sea or the Curonian Lagoon. The largest river in this basin is the Akmena-Danė, which flows out of the Coastal Lowland and enters the Baltic Sea via Klaipėda Strait.

Since 1990 the number of residents living in Lithuania has dropped by 883 000 inhabitants, which constitutes about 24% of the entire population (European Migration Network, http://123.emn.lt/en/). 177 000 can be referred to natural causes (birth/death rate), but the vast majority (707 000) is due to emigration. The immense emigration and unproportionable low immigration rates today leads to an array of challenges in Lithuania. One example is a major change in the demographic structure with an aging population. The same demographic trend has been observed in Klaipeda County in past three years. The number of County inhabitants have decreased from 324 618 to 317 252, or by almost 7 400. The same processes are taking place in coastal municipalities and municipal centres. Only the Klaipėda district municipality has an opposite process where the number of permanent residents instead are increasing. This is due to internal migration where people from Klaipeda and other surrounding municipalities are coming to the Klaipeda district.

According statistical data, the accommodation establishments of Lithuania received 3 250 000 tourists in 2017, which is 6.2% more than in 2016. Klaipėda county took the second place among the ten counties in Lithuania with 5.7 overnight stays per capita. The northern 52 km long stretch of the Curonian Spit peninsula, which belongs to Lithuania, is a UNESCO World Heritage Site and is among the most visited sites in Klaipeda County. 430 200 trips of inbound tourists (traveling tourists) visited Klaipeda, 160 300 visited Palanga and 87 500 Coronian Spit in 2017.

4.2 Wastewater management in the model area of Lithuania

According to the Lithuanian legislation, a public drinking water supplier and a WWTP are company controlled by the state or a municipality (municipalities) - shareholders. For this purpose, municipalities have established water and wastewater management companies that are owned by municipalities and are responsible for drinking water supply and/or wastewater collection and treatment in urban areas. Municipalities also own the water companies and WWTPs included in the MORPHEUS project.

Wastewater monitoring parameters and frequency are specified in the Integrated pollution prevention and control system, the IPPC permit. The IPPC permit contains authorized self-monitoring and includes two types of monitoring: control of treatment efficiency and control of treatment technological processes. Treatment efficiency self-monitoring includes nutrients (NO_3, NH_4, N_t, PO_4, Pt), organic matter (BOD_7) oxygenation (O_2), COD, hazardous substances (heavy metals), oil products and detergents depending on the size of plant and the type of activity. The main requirements for self-monitoring to be specified in IPPC permit are determined in the wastewater regulations. Until now no studies have been performed and no data is available on how much pharmaceuticals are removed during wastewater mechanical and/or biological treatment in Lithuania.

The operator of the treatment plant is responsible for the overall quality control of the wastewater treatment. Self-monitoring is performed by a water company owned and accredited wastewater research laboratory or commissioned to other accredited laboratories. For the enforcement of environmental law, environmental inspectors from the Ministry of Environment carry out wastewater quality regular compliance checks in accordance with the established control program or in the event of accidents or emergencies. Currently the pharmacological substances are not investigated in WWTPs, since these are not listed in the IPPC permit.

In 2017 Lithuania had 58 urban wastewater agglomerations of >2 000 PE. Six of them are situated in Klaipeda County, in the municipality's administration centers: Klaipėda, Palanga, Kretinga, Nida, Šilutė and Skuodas as shown in Figure 4.2.

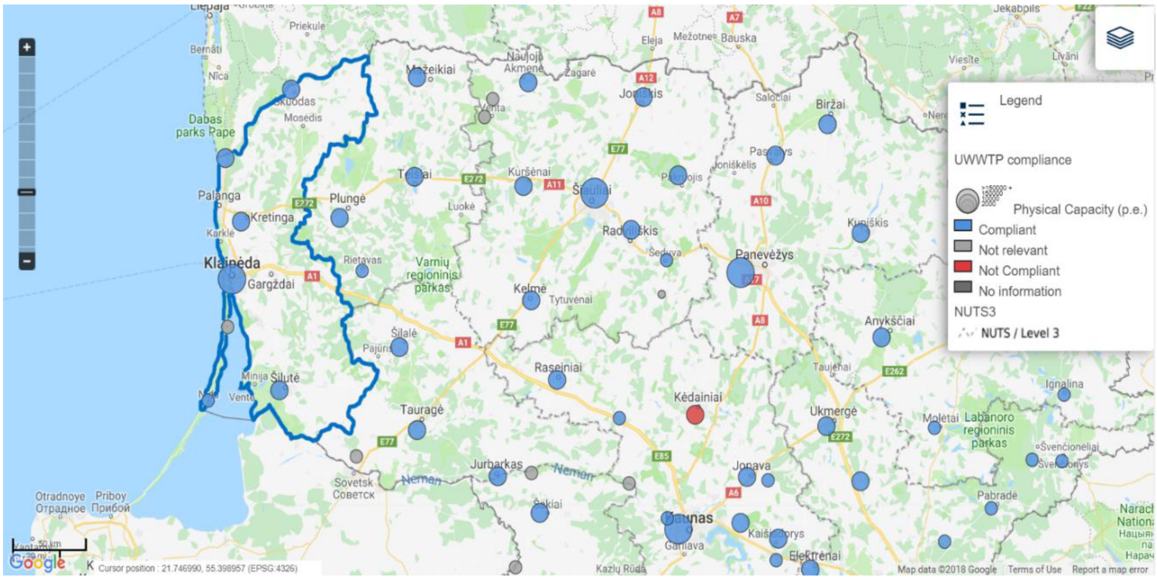

Figure 4.2 Urban Waste Water Treatment Directive (UWWTD) sites for Lithuania. (Source: http://uwwtd.oieau.fr/Lithuania/)

An overview of all WWTPs in Klaipeda county in terms of size and district is shown in Table 4.1. In all these WWTPs the wastewater was treated up to the established standards both in 2016 and 2017.

Table 4.1. *The number of WWTPs in the Klaipeda county municipalities*

	Municipalities, WWTPs	> 2 000 PE	< 2 000 PE	Total
1.	Klaipėda City Municipality	1	-	1
2.	Klaipėda District Municipality	-	14	14
3.	Kretinga District Municipality	1	12	13
4.	Neringa Municipality	1	3	4
5.	Palanga City Municipality	1	-	1
6.	Šilutė District Municipality	1	15	16
7.	Skuodas District Municipality	1	4	5
	Total	**6**	**48**	**54**

All treatment plants < 2 000 PE were constructed in small towns and settlements with a capacity ranging mostly from 40 to 250 m^3/d. The four model WWTPs, selected for the MORPHEUS project, are situated in the Lithuanian Coastal Rivers Basin which was assigned to the Nemunas River Basin District (RBD) according to WFD and occupies the area of 1 077 km^2, which makes up 2.3% of the total area of the Nemunas RBD.

4.3 Model wastewater treatment plants (M-WWTPs) in Klaipėda County

In April 2015 the Lithuanian Seimas (Parliament) approved the National Environmental Protection Strategy. The Strategy defines the priority areas of the environmental protection policy, with long-term objectives up to 2030 and a vision for the Lithuanian environment up to 2050. One of the aims for drawing up the Strategy was to establish horizontal long-term environmental objectives that would help the politicians, government and business representatives, social partners and society to choose a more precise line of action.

The objective in the field of water protection shall be to ensure a good status of groundwater, inland surface water bodies, the Curonian Lagoon and the Baltic Sea. The Strategy noted, that in the case of point source pollution, the pollution with hazardous substances remains one of the most important problems, as long as the volume and sources of such releases into water bodies as well as the status of water bodies with regard to such pollution have not been sufficiently analysed. It should be ensured that dangerous chemicals do not exceed the maximum permissible concentration in water bodies. Specific indicators and measures are set in the Water Resources Development Programme for 2017–2023 approved by the Lithuanian Government and Action Plan endorsed by the Ministry of Environment. Thus, the Programme and Action Plan outline these priority activities in the field of water protection:

- to increase efficiency of wastewater treatment in 12 WWTPs (all plants are situated outside the Klaipeda County area);
- to ensure that all generated wastewater is collected and treated in conformity with the established requirements;
- to ensure the development and modernisation of wastewater infrastructure, enhance accessibility of water supply and wastewater treatment services especially in small towns and settlement having 200 - 2 000 inhabitants.

New requirements will also be imposed to remove nitrogen and phosphorus from all WWTPs, both individual and agglomerations. However, there are no measures foreseen in the Programme and Action Plan to implement advanced treatment for removal of micropollutants in wastewater. However, in Kretinga WWTP a pilot investment in technological solutions for removing pharmaceuticals and other contaminants is planned to be introduced. This innovative approach is partly supported by EU Interreg South Baltic program project LESS IS MORE (https://southbaltic.eu/-/less-is-more).

Within the MORPHEUS project four Lithuanian WWTPs have been surveyed in details to recognised the current processes, challenges and needs according to Figure 4.3.

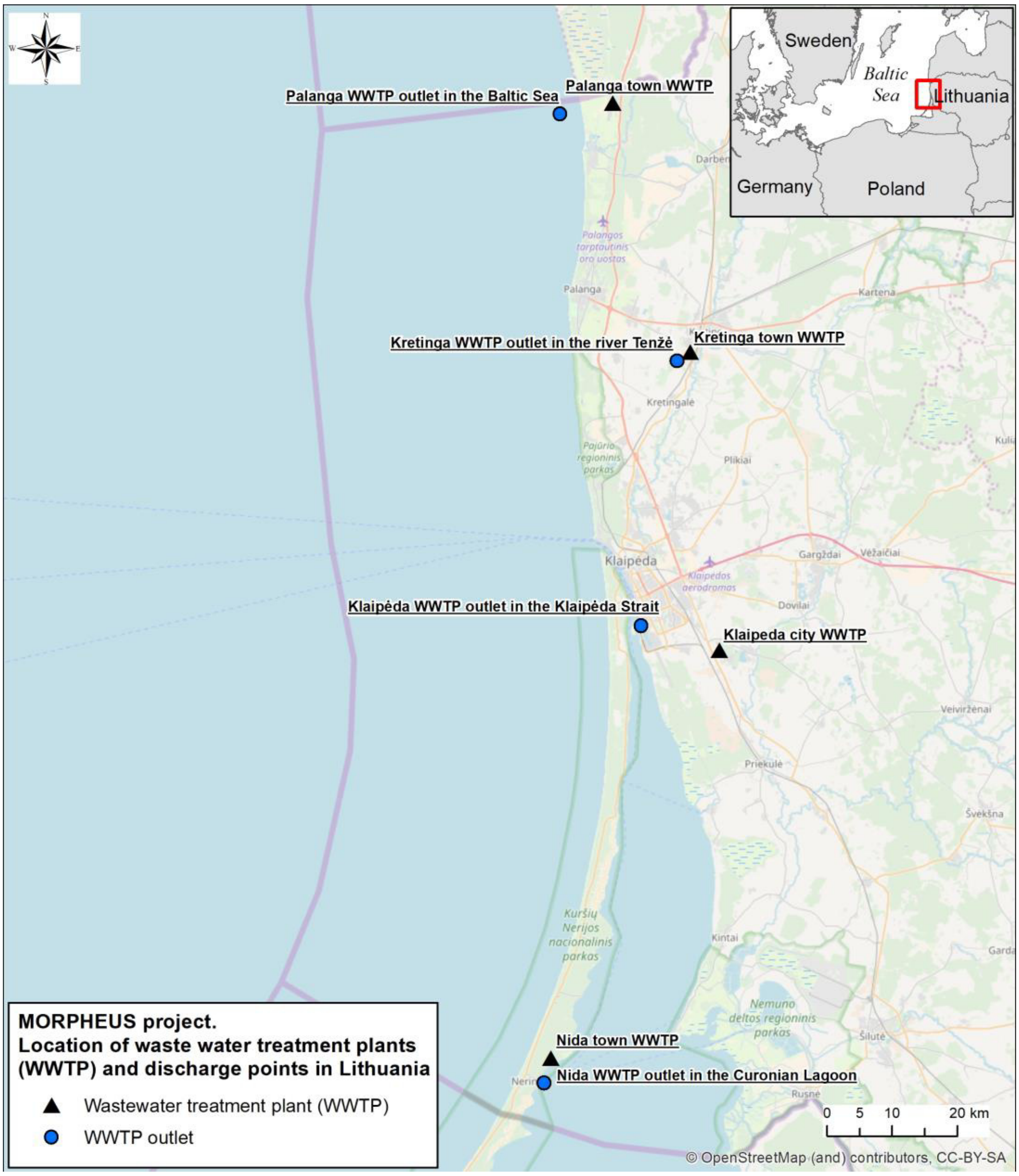

Figure 4.3. *Localization of M-WWTPs and their discharge points in the model area of Lithuania.*

4.3.1 Klaipėda WWTP

Klaipėda WWTP is situated in the southern part of Klaipeda city, approx. 6 km from the Curonian lagoon, serving 170 000 inhabitants of Klaipėda municipality and other small towns. It has a separated wastewater collection system with a designed capacity equal to 80 000 m^3/d (max. 95 000 m^3/d). The pollutant load corresponds to 259 429 PE (BOD_7).

In 2015 and 2016 the recorded average wastewater flows were equal to 41 013 m^3/d (14 969 770 m^3/year) and 41 256 m^3/d (15 099 820 m^3/year), respectively. The minimal wastewater flows were equal to 25 188 m^3/d in October 2015 and 26 695 m^3/d in June 2016, while maximal were 3-4 times higher and observed in March 2015 (70 912 m^3/d) and August

2016 (95 372 m^3/d), respectively. The difference between the summer season average flow (June to August) and the flow observed in the remaining period was significant only in 2015 with average values of 37 658 m^3/d and 42 143 m^3/d, respectively. In 2016 not much difference was observed with average values of 40 072 m^3/d and 41 654 m^3/d, respectively. The hydraulic retention time varied from 24-30 hours. Domestic wastewater comprised 68%, while industrial wastewater was the remaining part of the total inflow. The yearly average infiltration rate is equal to approximately 44%. The total pollutant load corresponded to 219 654 PE in 2015 and 215 299 PE in 2016. Inflow and outflow characteristic for Klaipėda WWTP in 2015 and 2016 is given in Table 4.2.

The Klaipėda WWTP treatment technology consists of a mechanical and a biological part:

- mechanical treatment: mechanical screens and aerated grit chambers are followed by primary sedimentation tanks.
- biological treatment: the University of Cape Town (UCT) system is an activated sludge technology used for conventional nitrogen and phosphorous removal with a sludge age of about 22 days; organic carbon is additionally used to support denitrification (poliflock MT 12 ECO).
- sludge treatment - sludge from the different processes is digested in mesophilic regime, then is dewatered in centrifuges, dried in dryer (SM approx. 95%) and in granules transferred to the final user - the composting company.
- WWTP outlet/discharge point - the treated wastewater is discharged via a ~10 km pipeline and underwater outlets installed in the Klaipeda seaport quay into the Klaipeda Strait which is a highly modified transitional water-strait connecting the Curonian Lagoon with the Baltic Sea.

Table 4.2. *Inflow and outflow characteristic for Klaipėda WWTP in 2015/2016 (Qav.2015 = 41 013 m^3/d and Qav.2016 = 41 256 m^3/d).*

Klaipėda WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits	-	15	125	10	1
Raw wastewater	-	353.4/355.4	703.8/761.1	79.5/87.3	8.9/8.7
Treated wastewater	2.03/4.72	3.85/5.55	44.44/45.52	9.63/9.93	0.28/0.36
Pollution load discharged to the receiver [t/year]					
Via treated wastewater	30.39/71.21	57.70/83.84	665.28/687.40	144.19/149.91	4.14/5.45

Current challenges and plans:

No changes are foreseen or planned at Klaipėda WWTP in the nearest future.

4.3.2 Palanga WWTP

Palanga WWTP is situated in the northern part of Palanga town, close to the Latvian border (0.85 km) and 2.5 km from the Baltic sea coastline, serving about 13 000 inhabitants of Palanga town municipality. It has a separated wastewater collection system with a designed capacity equal to 21 000 m^3/d and a pollutant load corresponding to 21 500 PE (BOD_7).

In 2015 and 2016 the recorded average wastewater flows were equal to 7 552 m^3/d (2 756 000 m^3/year) and 7 888 m^3/d (2 879 000 m^3/year), respectively. The minimal wastewater flows were equal to 4 312 m^3/d in 2015 and 5 344 m^3/d in 2016, while the maximal were 3-4 times higher with values of 13 496 m^3/d and 20 356 m^3/d, respectively. The summer season (June to August) the average wastewater flows were 9 277 m^3/d in 2015 and 9 933 m^3/d in 2016, and were higher than the flow observed in the remaining period: about 7 200 m^3/d in 2015 and 2016. The hydraulic retention times varied from 2 to 3 days. There is no industry in the Palanga WWTP serving area. Yearly average infiltration rate is equal to approximately 60%. The total pollutant load corresponded to 19 926 PE. Inflow and outflow characteristic of Palanga WWTP in 2015 and 2016 is given in Table 4.3.

The Palanga WWTP treatment technology consists of a mechanical and a biological part:

- mechanical treatment: mechanical screens and aerated grit chambers are followed by primary sedimentation tanks.
- biological treatment: the A2O system is an activated sludge technology used for conventional nitrogen and phosphorous removal with denitrification basin followed by, anaerobic, anoxic and oxic phases; with a sludge age of about 32 days; the wastewater stream entering the biological part is divided to support denitrification and dephosphatation.
- sludge treatment - sludge from the different processes is first flocculated, then mechanically dewatered by screw press, then stored in temporary storage yards, and finally used as fertilizer.
- chemical treatment: Al2O3 and Brentaplus VP1 is applied very rare.
- WWTP outlet/discharge point: the Baltic Sea coastal waters, (Natura 2000). Due to pipeline damage the exact location of the discharge point is currently not specified, however the previous outlet location was 2.15 km from the Baltic Sea shore.

Table 4.3. *Inflow and outflow characteristic for Palanga WWTP in 2015/2016 (Qav.2015 = 7 552 m^3/d and Qav.2016 = 7 888 m^3/d).*

Palanga WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits	-	15	125	15	2
Raw wastewater	221.9/216.4	163.5/177	np/379.9	41.01/40.9	7.52/7.75
Treated wastewater	3.99/5.82	2.87/2.99	2.4/2.61	5.38/4.60	0.37/0.59
Pollution load discharged to the receiver [t/year]					
via treated wastewater	11.50/16.76	7.92/8.62	np./108.11	15.61/13.25	0.95/1.69

np - not provided

Current challenges and plans:

In the nearest future the activated sludge mixers are going to be modernised.

4.3.3 Kretinga WWTP

Kretinga WWTP is situated approximately 3.5 km southwest from the center of Kretinga and serves mainly inhabitants of Kretinga town which had 18 127 inhabitants in 2015 and 19 150 in 2016. It has a separated wastewater collection system with a designed capacity equal to 5 160 m^3/d. In 2015 and 2016 the recorded average wastewater flows were equal to 3 576 m^3/d (1 305 300 m^3/year) and 4 031 m^3/d (1 471 300 m^3/year), respectively. The minimal wastewater flows were equal 1 505 m^3/d in November 2015 and 2 087 m^3/d in July 2016, while the maximal were several times higher with values of 14 480 m^3/d in January 2015 and 10 510 m^3/d in February 2016. The summer season average flows (June to August) were lower than the flows observed in the remaining period. In 2015 the flows were equal to 2 594 m^3/d and 3 907 m^3/d, respectively, while in 2016 corresponding values were 3 363 m^3/d and 4 103 m^3/d, respectively. The hydraulic retention times varied from 1 to 2 days. The domestic wastewater comprised 75%, while industrial was the remaining part of the total inflow. Yearly average infiltration rate is equal to approximately 60%. Total pollutant load (BOD_7) corresponded to 18 151 PE in 2015 and 23 944 PE in 2016. Inflow and outflow characteristic of Kretinga WWTP in 2015 and 2016 is given in Table 4.4.

The Kretinga WWTP treatment technology consists of a mechanical and a biological part:

- mechanical treatment: mechanical screens and aerated grit chambers are followed by primary sedimentation tanks.
- biological treatment: AO system, activated sludge technology used for conventional nitrogen removal with a sludge age of about 22 days.
- sludge treatment: sludge is firstly flocculated, then mechanically dewatered by screw press, then stored in temporary storage yards, and finally used as fertilizer.
- WWTP outlet/discharge point: the River Tenžė which is a straightened drainage ditch and a tributary of the Akmena-Danė river.

Table 4.4. *Inflow and outflow characteristic for Kretinga WWTP in 2015/2016 (Qav.2015 = 3 576 m^3/d and Qav.2016 = 4 031 m^3/d).*

Kretinga WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits	-	10	125	10	1
Raw wastewater	286.1/404.5	429.6/499.0	960.4/897.5	73.0/68.1	11.8/11.0
Treated wastewater	5.58/9.07	3.75/4.17	30.3/30.1	6.48/5.45	0.56/0.41
Pollution load discharged to the receiver [t/year]					
Via treated wastewater	7.29/13.34	4.90/6.13	39.84/44.30	8.46/8.01	0.73/0.61

Current challenges and plans:

In the nearest future a pilot investment is planned connected with technological solutions for removing pharmaceuticals and other contaminants of emerging concern funded by the Interreg South Baltic project LESS IS MORE.

4.3.4 Nida WWTP

Nida WWTP is situated in the northern part of Nida settlement – the most southerly settlement of the Curonian Spit, and serves mainly inhabitants of Nida town with ca 1 700 inhabitants. It has a separated wastewater collection system with a designed capacity equal to 1 700 m^3/d. In 2015 and 2016 the recorded average wastewater flows were equal to 620 m^3/d (226 151 m^3/ year) and 630 m^3/d (229 883 m^3/year), respectively. The maximal wastewater flows are usually noted in the summer season with flows of 1 515 m^3/d in July 2015 and 1 903 m^3/d in August 2016, while the minimal were several times lower with flows of 291 m^3/d in November 2015 and 267 m^3/d in October 2016. In the summer season average flows (June to August) were two times higher than the flows observed in the remaining period and in 2015 they were 970 m^3/d and 501 m^3/d, respectively, while in 2016 they were 1 037 m^3/d and 493 m^3/d, respectively. The hydraulic retention times varied from 1 to 3 days. There is no industry in the Nida WWTP serving area. Inflow and outflow characteristic of Nida WWTP in 2015 and 2016 is given in Table 4.5.

The Nida WWTP treatment technology consists of a mechanical and a biological part:

- mechanical treatment: mechanical screens and aerated grit chambers are followed by primary sedimentation tanks.
- biological treatment: AO system, activated sludge technology used for conventional nitrogen removal with a sludge age of about 27 days.
- sludge treatment: sludge is firstly flocculated, then mechanically dewatered by a screw press, than stored in temporary storage yards, and finally used as fertilizer.
- WWTP outlet/discharge point: Curonian lagoon (transitional waters) where some of the Curonian Lagoon's waters fall into the Curonian Spit National Park and biosphere polygon. Treated sewerage is discharged into the Curonian Lagoon by an about 450 meters long underwater pipe at a 2.5 m depth.

Table 4.5. Inflow and outflow characteristic for Nida WWTP in 2015/2016 (Qav.2015 = 620 m^3/d and Qav.2016 = 630 m^3/d).

Nida WWTP	TSS mg/dm^3	BOD_7 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits	-	29	125	-	-
Raw wastewater	896/677	495/347.69	999/755.9	149/87.53	28.3/9.44
Treated wastewater	12.0/12.65	5.8/5.11	48/54.97	18.1/18.98	2.9/3.58
Pollution load discharged to the receiver [t/year]					
Via treated wastewater	2.76/2.91	1.30/1.17	10.75/12.64	4.09/4.36	0.66/0.82

Current challenges and plans:

No changes are foreseen or planned at Nida WWTP in the nearest future.

4.4 Prospects and challenges for M-WWTPs in Lithuania

The seasonal variability of sewage flow does not influence treatment quality at Klaipeda WWTP and Palanga WWTP, but require higher operating costs. More noticeable on the treatment quality than the increase of population in the summer season is the infiltration rate, which at Palanga WWTP reaches up to 60%. In the nearest future a pilot investment is planned for removing pharmaceuticals and other contaminants of emerging concern. This is funded by the Interreg South Baltic project LESS IS MORE. Other investments planned in the Lithuanian model area are connected with the WWTPs serving up to 2 000 inhabitants, which are going to be modernised or developed.

5. Survey on wastewater treatment in the model area in Germany - Baltic Sea catchment within the Federal State Mecklenburg-Vorpommern, esp. the sub-catchments of the rivers Warnow/Peene, Schlei/Trave as well as the German side of the Oder (2015)

5.1 The State Mecklenburg- Western Pomerania– general information

Most of the German Baltic Sea Catchment Area is located within Mecklenburg-Western Pomerania (German: Mecklenburg-Vorpommern) which is one out of 16 Federal States covering app. 23 000 km² (see Figure 5.1). Around 75% of the catchment areas within the Federal State are discharging into the Baltic Sea, the remaining ones in the south-west via the river Elbe into the North Sea.

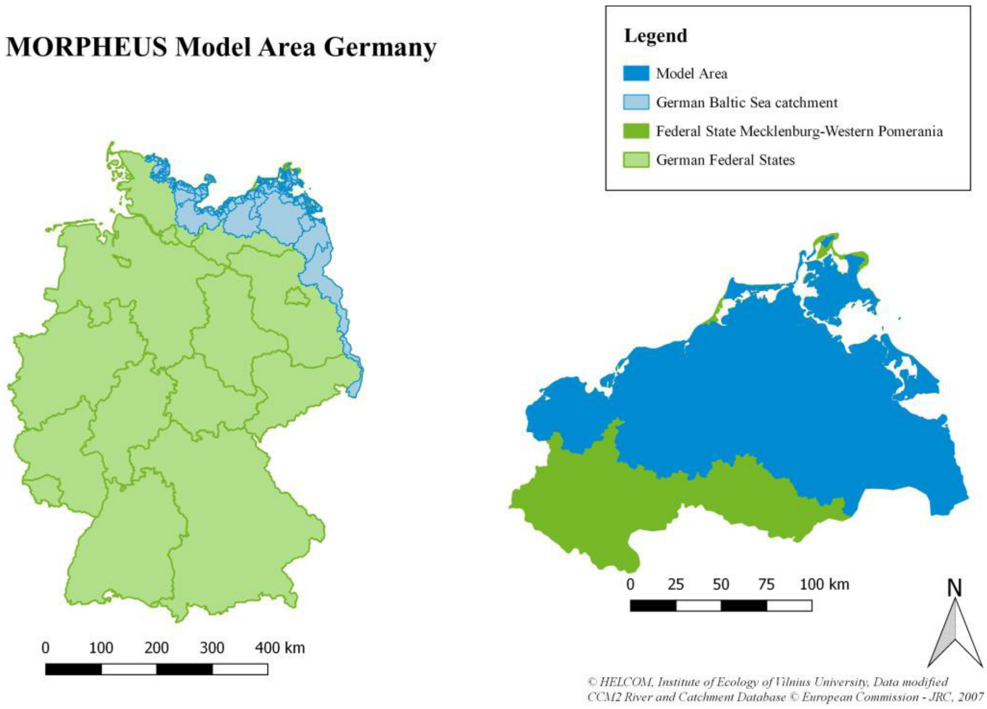

***Figure 5.1**. German Model Area and Baltic Sea catchment*

Beside the capital Schwerin (nearly 100 000 inh.), Rostock is the largest city (about 205 000 inh.). Mecklenburg-Western Pomerania is the least densely populated and least industrial state in Germany with a total population of 1 610 674 (2015) equal to 69 persons/km² (compare German average: 232 persons/km²).

In this area large wetland areas, rivers and streams are fed mainly by groundwater inflow. These river systems are strongly cross-linked and characterized by the numerous small water bodies and ditches. Due to the sparseness of population and good quality of primary clayey soil, the landscape is dominated by rural areas with more than 60% land use in agriculture and app. 22% covered by forest. Furthermore, more than 2000 lakes characterize the landscape.

About 2000 km coastline of the Baltic Sea provides numerous opportunities for the strong tourism in this region. Combined with the beautiful landscape, hundreds of nature reserves and large islands alongside the coast, the Federal State became Germany's leading intra-German tourist destinations and gained importance for international tourism. Besides tourism, the economy is mainly driven by manufacturing industry, followed by the service sector, health services and agriculture. Additionally, two of the oldest universities (both German and all over Europe) are located in Mecklenburg-Western Pomerania: The University of Rostock (founded 1419) and the University of Greifswald (founded 1456) are, next to several colleges/technological universities, the main centers of attraction for young students and scientists. Therefore, modern techniques as well as highly specialized sectors are growing sectors in this region, too. Especially within the sector renewable energy, Mecklenburg-Western-Pomerania is one of the leading specialists which can also be seen in the landscape where more than 1800 wind power plants are installed.

According to German law, in general the communes and municipalities are responsible for drinking water supply. They can execute the task officially themselves or contract private operators. In rural areas, small communes are organized in administration unions which are both responsible for water supply and wastewater disposal. Therefore, the wastewater management is extremely compartmentalized (nearly 7000 operators) all over the country, whereby the majority is organized by either administration unions (34%) or owner-operated municipal enterprises (35%). In Germany there are several classes of WWTPs as shown in Table 5.1. The WWTP size classes 4 and 5 treat 90% of the total wastewater but represent not even a quarter of the WWTP amount in Germany.

***Table 5.1**. Treated wastewater according to WWTP size classes in Germany (2014)*

Size class (design size in PE)	Number of WWTP	Total capacity (PE)	Share (%) of treated wastewater
5 (>100,000)	232	80 823 334	52
4 (10,001 -100,000)	1 908	61 970 739	38
3 (5,001-10,000)	870	6 686 511	4
2, 1 (50-5,000)	6 468	7 283 708	6

source: Datenlieferung der Bundesrepublik Deutschland an die EU-Kommission zur Umsetzung der Kommunalwasserrichtlinie (2014), UBA report water management in Germany (2017)

The main research issues regarding WWTPs in Germany are related to phosphorus removal, energy footprints, sludge treatment and recycling as well as specific process technologies. In terms of introducing advanced treatment of micropollutants, Germany is one of the leading countries in research and has already installed or planned more than 70 WWTP applying either ozonation or activated carbon treatment, though not in the model area of MORPHEUS. All together there are today more than hundred feasibility studies. The heartland of pharmaceutical removal techniques is located in the Federal States Berlin, North Rhine-Westphalia and Baden-Wuerttemberg. In these areas competence centers are in close collaboration with experts from Switzerland, who also have started to upgrade several of their larger WWTPs with advanced treatment. In Germany, the limit values of pharmaceutical concentrations in surface water bodies are still under progress considering PNEC and substances of the EU watchlist among others. Currently, a so called “stakeholder dialogue” on the most efficient ways of handling pharmaceutical pollution is ongoing, moderated by the Federal Ministry of Environment and its subordinated authority “Umweltbundesamt” (UBA).

5.2 Wastewater Management in the Model Area

In the Federal State Mecklenburg-Western Pomerania, 110 wastewater treatment operators are in charge of app. 15 720 km canalization and 586 WWTPs. The actual degree of connectivity is about 90% which is acceptable due to the sparsely populated areas. Out of these 586 WWTPs, only 51 are classified to size class 4 or 5 whereby they treat 84% of the wastewater (Table 5.2). Therefore, these few plants are mainly relevant for emissions into the Baltic. However, from the perspective of ambient water quality with regard to the EU-WFD, the smaller WWTPs are often decisive. This applies especially, when discharging into small receiving water bodies or upstream lakes.

Table 5.2. *Treated wastewater according to WWTP size classes in the Model Area of the Federal State Mecklenburg-Vorpommern, Germany (2014)*

Size class (design size in PE)	Number of WWTP	Total capacity (PE)	Share (%) of treated wastewater
5 (>100,000)	4	940 000	28.6
4 (10 001 -100 000)	47	1 820 250	55.4
3 (5 001-10 000)	21	166 892	5.1
2 (1 000-5 000)	86	214 870	6.5
1 (<1 000)	428	144 939	4.4

source: Lagebericht 2017, Kläranlagen in MV, LUNG (2017)

All of the reported treatment plants operate mechanical and biological treatment techniques, even those with below 2 000 PE. WWTP larger than 10 000 PE do also include nitrification, denitrification as well as phosphorus elimination. 90% of the total PE in the Federal State are connected to central WWTP. The predominantly installed techniques are activated sludge plants, sequencing batch reactors (SBR) and ponds. Trickling filters and rotating biological contactors are rare. The remaining 10% are obliged to install septic tanks, in 2017 app. 60 plants for hotels, camping sites etc. (50-1 250 PE), 56 500 private tanks (<50 PE) and 18 300 wastewater collecting pits were registered. By development funds, these septic tanks have been/will be upgraded to actual technique standards.

Industrial wastewater is directly discharged into the surface waters by 6 agglomerations. All of them treat their wastewater at least mechanically-biologically, 4 of them also apply nitrification, denitrification and/or phosphorus elimination. The WWTP sludge amount was documented with 39 255 tons dry matter including supplements for stabilization and conditions of sludge in 2015.

Till 2016, more than 60% of this sludge was used as fertilizer in agriculture, and imported sludge was applied, too. With changes in legal settings, mainly the fertilizer ordinance, the disposal sewage sludge in agriculture becomes more and more difficult. Besides, the new sewage sludge ordinance bans this disposal way for WWTP larger than 50 000 PE (with a tolerated transition period of 10 years). Advanced treatment is not yet implemented in any WWTPs in this region but gains increasing attention by public authorities.

5.3 Model wastewater treatment plants (M-WWTPs) in Germany

In total 3 model wastewater treatment plants M-WWTPs were chosen for the survey of existing technology: Rostock WWTP, Laage WWTP and Krakow/Charlottenthal WWTP as shown in Figure 5.2.

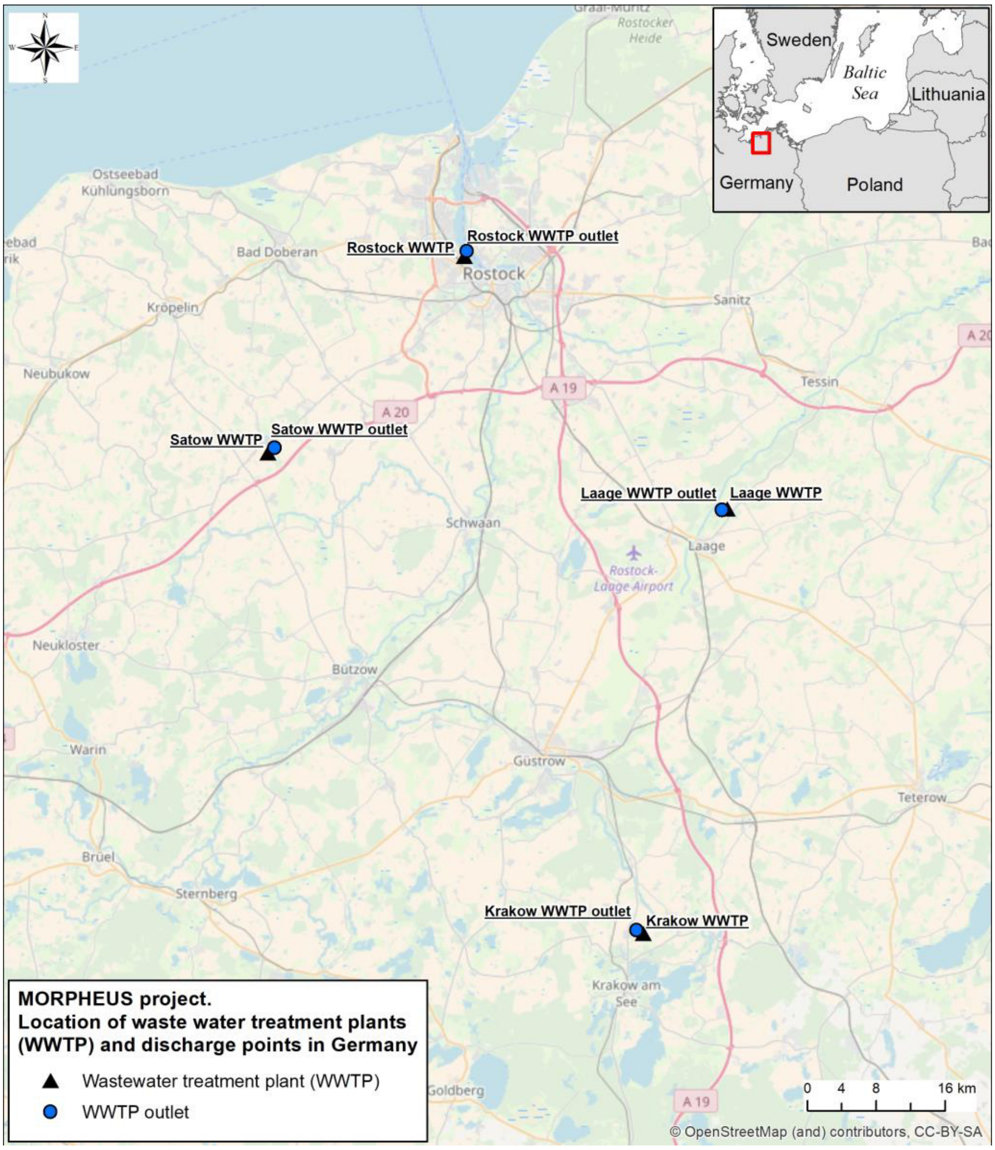

Figure 5.2. *Localization of M-WWTPsand their discharge points in the model area of Germany.*

5.3.1 Rostock WWTP

The Central WWTP of Rostock is located directly in Rostock close to the river Warnow currently serving 235 645 persons including both inhabitants of Rostock Municipality and other small nearby villages. It has a combined wastewater collection system. During dry-weather-flow the designed capacity of Rostock WWTP equals 65 000 m^3/d, while for combined sewage flow it is 96 000 m^3/d. The designed pollutant load corresponds to 400 000 PE (BOD_5).

In 2015, the noted average wastewater flow was equal to 42 314 m^3/d, and varied from 29 245 m^3/d (in May) to 79 275 m^3/d (in January). The difference of wastewater volume in the summer season from June-August with and average flow of 40 367 m^3/d and in remaining period with an average flow of 42 966 m^3/d was not significant. The hydraulic retention times varied from 1 to 2 days. Domestic and industrial wastewater comprised 80% of the total inflow, while storm/rain water constituted the remaining part. Total pollutant load corresponded to 342 483 PE. Inflow and outflow characteristic of Rostock WWTP in 2015 is given in Table 5.3.

The WWTP Rostock treatment technology consists of mechanical and biological steps:

- mechanical treatment: 3 mechanical fine screens (6 mm) and aerated grit chambers are followed by two primary settlement tanks.
- biological treatment: the 1st biological treatment stage consist of bio-P-tank, pre-denitrification (VBB=30 000 m^3), pressure aeration by turbo compressor and clarification (with sludge age from 10 to 12 days); the 2nd biological treatment stage consist of fine screen (2 mm), BIOFOR®-N, BIOFOR®-DN and methanol-dosing. Biofiltration facility carries out the final cleaning process (post-nitrification and post-denitrification step) before the wastewater is discharged into the Warnow. BIOFOR stands for “biological fixed film reactor”. The Bio-filtration facility has an overall filter area of 876 m^2, distributed among a total of 12 nitrification and 12 de-nitrification filters. As a filter material and carrier for the microorganisms expanded clay is used. Once the aerobic bio-filtration phase has been completed, addition of iron(III)chloride allows to achieve phosphate precipitation. In general, two filters are always working at the same time, with the filter velocity between 5.2 m/h in dry weather and 8.7m/h during rain events. If the filter velocity exceeds 8 m/h, then another is activated. When the velocity slows down below 3 m/h then a filter is turned off.
- sludge treatment: sludge from the different processes undergoes thickening (static, flotation), mesophilic digestion (with desulphurisation), dewatering (centrifuges), gas utilization (co-generation unit) and final incineration.
- WWTP outlet/discharge point: the treated wastewater is discharged into the Unterwarnow, which is an estuary-like tributary of the Baltic Sea.

Table 5.3. Inflow and outflow characteristic for Rostock WWTP in 2015 (Qav. = 42 314 m³/d)

WWTP Rostock	TSS mg/dm³	BOD_5 mg O_2/dm³	COD mg O_2/dm³	N_{tot} mg N/dm³	P_{tot} mg P/dm³
Discharge limits (size class 5: PE >100,000)	-*	15	75	13	1
Raw wastewater	-*	np	np	np	Np
Treated wastewater	-*	2.1	34	15.1	0.18
Pollution load discharged to the receiver [t/year]					
via treated wastewater		np	np	np	Np.

*) TSS is analysed only for specialized industrial wastewaters; np – not provided

5.3.2 Laage WWTP

Laage WWTP is a characteristic activated sludge plant performing aerobic sludge stabilisation. This technology is typical for rural WWTP. It waives for reasons of simplicity a primary clarification and anaerobic digestion. The Laage WWTP is located south of Rostock in a rural area serving 4 516 inhabitants of villages within Rostock County. It has a separated wastewater collection system, with a designed capacity equal to 3 600 m³/d and pollutant load corresponding to 20 000 PE.

In 2015, noted average wastewater flow was equal to 880 m³/d, and varied from 445 m³/d to 2 210 m³/d. The difference in wastewater volume in the summer season June-August with an average flow of 838 m³/d and the remaining period with an average flow of 894 m³/d was not significant. Hydraulic retention time at Laage WWTP is equal to 1 day. Domestic wastewater comprised 37% of total inflow and industrial wastewater 63%. Yearly average infiltration rate is equal to 14.7%. Total pollutant load corresponded to 12 658 PE. Inflow and outflow characteristic of Laage WWTP in 2015 is given in Table 5.4.

The Laage WWTP treatment technology consists of mechanical and biological treatment:

- mechanical treatment: mechanical screens followed by aerated grit chamber.
- biological treatment: conventional nitrification and denitrification process with a sludge age equal to 43 days.
- sludge dewatering: finally sludge is used in agriculture.
- WWTP outlet/discharge point: the treated wastewater is discharged into the River Recknitz, which is a direct tributary to the Baltic Sea with its outlet near the town Ribnitz-Damgarten.

Table 5.4. Inflow and outflow characteristic of WWTP Laage in 2015 (Qav. = 880 m³/d).

WWTP Laage	TSS mg/dm³	BOD_5 mg O_2/dm³	COD mg O_2/dm³	N_{tot} mg N/dm³	P_{tot} mg P/dm³
Discharge limits (size class 4: 10,000 < PE <100,000)	-*	20	90	18	2
Raw wastewater	-*	822	1 978	115	29.4
Treated wastewater	-*	np	np	np	np
Pollution load discharged to the receiver [t/year]					
via treated wastewater	-	np	np	np	np

*) TSS is analysed only for specialized industrial wastewaters; np – not provided

5.3.3 Krakow/Charlottenthal WWTP

Krakow/Charlottenthal WWTP is located in a rural area serving 3 964 inhabitants in the south of Rostock County. It has a separated wastewater collection system, with a designed capacity equal to 1 450 m^3/d, and a pollutant load corresponding to 7 500 PE.

In 2015, the noted average wastewater flow was equal to 630 m^3/d, and varied from 187 m^3/day to 1 176 m^3/d. The difference in wastewater volume in the summer season June-August with an average flow of 465 m^3/d) and the remaining period with an average flow of 685 m^3/d) was not significant. Hydraulic retention time at Krakow/Charlottenthal WWTP is equal to 1 day. Domestic wastewater comprise 64% of total inflow, while industrial wastewater represent 36%. Yearly average infiltration rate is equal to 3.9%. Total pollutant load corresponded to 6 209 PE. Inflow and outflow characteristic of Krakow/ Charlottenthal WWTP in 2015 is given in Table 5.5

The Krakow/Charlottenthal WWTP treatment technology is similar to Laage WWTP. It consists of mechanical and biological parts:

- mechanical treatment: mechanical screens followed by aerated grit chamber.
- biological treatment: conventional nitrification and denitrification process with sludge age equal to 35 days.
- sludge dewatering: sewage sludge is finally used in agriculture.
- WWTP outlet/discharge point: the treated wastewater is discharged by a ditch draining into the river Nebel, which is a tributary of the river Warnow finally entering the Baltic Sea.

Table 5.5. *Inflow and outflow characteristic of WWTP Krakow/Charlottenthal in 2015 (Qav. = 630 m^3/d)*

Krakow/ Charlottenthal WWTP	TSS mg/dm^3	BOD_5 mg O_2/dm^3	COD mg O_2/dm^3	N_{tot} mg N/dm^3	P_{tot} mg P/dm^3
Discharge limits (size class 3: 5,000< PE <10,000)	-*	20	90	nt	nt
Raw wastewater	-*	656	1 259	112	17.2
Treated wastewater	-*	np	np	np	np
Pollution load discharged to the receiver [t/year]					
via treated wastewater	--	np	np	np	np

*) TSS is analysed only for specialized industrial wastewaters; nt - not tested, np - not provided

5.4 Prospects and challenges for M-WWTPs in Germany

As a result of the population pressure and uneven distribution of rural and urban areas, regional variations determine the different challenges for WWTPs in Germany. Agglomerations such as major cities and the Rhine-Ruhr-area in North Rhine-Westphalia have a significantly increased pressure to act within the catchments due to dense population and pollutants built-up. This leads to expanded research and application of related technologies especially within the agglomerations.

Mecklenburg-Western Pomerania has not yet implemented any advanced treatment. According, to the Water Framework Directive none of the coastal waters is in a good ecological condition. So far, measures to improve coastal water quality focus on nutrient removal, namely phosphorous and nitrate. Most of the largest WWTP are located along the coastal line. Especially these coastal WWTPs are discharging their treated wastewaters nearly directly into the Baltic Sea. Therefore, the main need for action could be seen here. Considering the WFD and the quality of inland water bodies within the catchment, numerous smaller WWTP (>500) are important to investigate, too. Since advanced treatment is not cost-efficient at these German WWTPs, the question of potential near-natural solutions such as photolytic degradation in ponds arises and may be discussed in the future in Germany.

At this stage of knowledge related to pharmaceutical substances and transports into the Baltic Sea, a structured analysis of the current status is crucial in order to understand the situation. MORPHEUS and a corresponding mass flow analysis could improve the knowledge base for decision makers in politics and administration, significantly. Parallel applied research of Rostock University aims at finding appropriate treatment technologies for the largest WWTP.

6. Conclusions

The present report in the MORPHEUS project, formally called “Deliverable 5.1 - Inventory of existing treatment technologies in WWTP in partner regions”, examines the status of existing treatment technologies currently used in the wastewater sectors in four coastal model areas in the South Baltic Sea. In total 14 model WWTPs in Poland (4), Sweden (3), Lithuania (4) and Germany (3) were selected (see APPENDIX 1). In general over 80% of the population was connected to the existing WWTPs in these areas; 83% in Pomerania Voivodeship, Poland, 90% in Skåne County, Sweden (estimated based on national data), 63% in Klaipėda County, Lithuania, and 90% in Mecklenburg-Western Pomerania, Germany. Essentially, in urban areas almost all households are served by WWTPs with advanced biological nutrients removal, most often supported by chemical treatment, mainly for phosphorus precipitation. Their effectiveness is crucial since the largest WWTPs are often located along the coastal line and discharge directly into the Baltic Sea. However, also inland WWTPs may cause an environmental burden if they release treated wastewater to rivers that end in the Baltic Sea as is the case for several WWTPs in these coastal regions.

Another concern in some of the selected areas is the large number of tourists arriving during the summer period which increases the pressure on existing wastewater infrastructure during this part of the year. Tourism is in important part of the economy in these coastal areas, but must be taken into consideration when developing these areas further so that wastewater is handled in an appropriate way. This is important to avoid deterioration of the sensitive coastal ecosystems and maintain them for the future to the benefit of both permanent residents and the tourist they are depending on.

An important challenge in the wastewater sector is ensuring that also rural areas have access to properly working wastewater collection and treatment systems. The small-scale WWTPs, serving the small agglomerations may reduce nutrients with limited effectiveness. Additionally, those facilities are in some areas usually old and need upgrading. The effluent discharge from these systems primarily impacts the local catchments but may lead to contamination of groundwater/bathing sites and in worst case make drinking water unusable.

The situation related to connection of households to WWTPs changes continuously, and housing developments outside the cities may help replace smaller local WWTPs with pumping stations that transfer sewage to larger, better equipped and more advanced WWTPs. In some of the model areas centralized treatment at major WWTPs is already a reality and further planning is made to build even larger WWTPs the coming decade, replacing a number of smaller WWTPs.

Additionally, besides enabling better phosphorus and nitrogen removal, it is very important also to understand the micropollutants being released via treated wastewater. The presence of organic compounds with limited biodegradability in the municipal wastewater is due to an ever-increasing amount of chemicals used by householders. Everyday lives introduce a wide range of chemicals into our wastewater systems, mainly surfactants, skincare products, disinfectants, flame retardants, pesticides, insecticides, plasticizers and pharmaceuticals and their metabolites. Some of the above substances may be replaced by more biodegradable “green” detergents, while the presence of e.g. pharmaceuticals and their metabolites cannot easily be reduced as we are very depending on most of our existing pharmaceuticals in the healthcare sector. Here it could also be noted that the concentration of pharmaceuticals may increase due to an aging society. Some of the investigated model areas has a demography that shows such an increase in elderly people. In this respect the discharge of the wastewater originating from the hospital sectors to municipal sewer should also be consider. In most cases the contribution of wastewater from hospitals is low, and only constitutes a few percent in the model areas, but this water could possibly contain specific pharmaceuticals of concern that are only given as special treatments at hospitals. In areas with an aging population an increase in the amount of water from hospitals to WWTPs is not unlikely and may be part of the planning of future investments in wastewater treatment in various regions.

In terms of micropollutants, the industrial wastewater sector should also be considered. Industrial wastewater is often treated in dedicated treatment plants or onsite pretreated before discharge to the municipal system. Such onsite pre-treatment of industrial wastewater, however, is often limited to only the removal of nutrients and organic matter susceptible to biodegradation, while the compounds with limited biodegradation (as micropollutants) are still directed to the municipal WWTPs.

Overall it can be expected that the elimination of at least some micropollutants in better equipped and better controlled WWTPs will be more efficient, but this will be addressed in a coming report presenting data for occurrence of pharmaceuticals in both incoming and outgoing wastewater from the 14 selected WWTPs (Deliverable 4.1 - Report on pharmaceutical chemical burden in four coastal regions SE, DE, PL, LT).

Public awareness on sustainable water management is very important in this process, due to their dual role as polluters and beneficiaries of proper water/wastewater management. Additionally, currently wastewater sector should adopt a holistic management approach, which means that all activities need to be taken under consideration. The wastewater treatment efficiency is highly connected with the sewage sludge production and management (also in terms of micropollutants dissemination) and both influence the energy consumption. Thus, implementation of any new technology in the wastewater treatment sector requires deeper understanding of all processes, because they influence each other.

Another very important challenge is providing knowledge transfer, proper education and training. All above should include local authorities and WWTPs exploiters. In this process the key role may be played by local universities and expert organizations, due to their expected objectivity.

It can be concluded that in the area covered by the MORPHEUS project progress has been made in understanding the treatment of nutrients in the wastewater sector. However, the increasing demand of potable water as well as the protection of water resources in general, including sensitive aquatic ecosystems further addresses the challenge of micropollutants in the South Baltic Sea.

Both Sweden and Germany have already started to take action on removal of micropollutants by advanced treatment. In Region Skåne as well as in other parts of Sweden, several pilot-plants utilizing activated carbon and/or ozonation has been running the past few years, while in

Germany several small and large WWTPs have been in operating with such technologies for several years, in some cases for a decade. However, in Mecklenburg-Vorpommern (Germany) no advanced treatment has been introduced.

In Poland and Lithuania this topic is still mainly at the discussion stage, though a small advanced treatment plant will be built in Lithuania within short as part of another Interreg South Baltic project named LESS IS MORE. Nonetheless the wastewater treatment industry seems to be motivated to develop advanced treatment strategies that are cost effective, acceptable by society and have less of an environmental impact. An overview of some of the recently developed and tested advanced treatment technologies will be made available in a coming report within MORPHEUS (Deliverable 5.2 - Overview of advanced treatment technologies).

Up to now the very incomplete knowledge related to pharmaceutical occurrence pattern in wastewater in WWTPs in the four coastal regions of MORPHEUS and their transports into the South Baltic Sea limits a proper implementation of advanced treatment technology. But the actions undertaken within the MORPHEUS project intends to at least partly fill this gap, with this report being the first step in this direction.

APPENDIX 1.

Summary of model WWTPs – parameters and technology for 2015

WWTP	Q [m³/day]	PE	inhabitants connected [number]	Q_{av} [%]	wastewater treatment scheme	$TSS/BOD_5/COD/N_{tot}/P_{tot}$ [mg/dm³]	receiver	notes
	designed average in 2015			industry hospitals		raw wastewater treated wastewater		
M-WWTPs in the model area of Poland (PE as BOD_5)								
Gdansk-Wschod	1 200,000 92 958	840 200 742 521	571 350	11% <1%	A2/O	529/467/986/91/11 6/3/32/8/<1	Gdansk Bay (Natura 2000)	
Gdynia-Debogorze	73 000 55 294	440 000 476 000	360 000	10% 0.1%	Bardenpho with Carussel system (simultaneous DN)	488/474/1090/95/12 0.1/0.1/30/7.4/0.6	Puck Bay (Natura 2000)	
Sawarzewo	18 000 6 164	180 000 149 000	35 668	5% < 1%	SBR. N/DN	814/775/1674/131/19 8.4/5.7/39/18/2.2	Baltic Sea	flow and load are entering the WWTP seasonally influenced by tourism and due to combined sewage system
Jastrzebia Gora	7,305 1 678	62 000 12 540	3 500 (30 000 in summer season)	-	modified Bardenpho; UV disinfection of final effluent	488/474/1090/95/12 4.7/2.3/31/6/0.4	Czarna Wda river	flow and load are entering the WWTP seasonally influenced by tourism
M-WWTP in the model area of Sweden (PE as BOD_7, data provided for 2016)								
Kristianstad	np 22 427	205 000 118 000	52 000	54% np	N/DN chemical P	nt/369/882/49/8.3 nt/1.9/28/6/0.07	Ditch draining into Hammarsjön Lake (Natura 2000, Ramsar site, Unesco Biosphere Reserve “Vattenriket”)	The number of tourist per year is ~ 28 000

Tollarp	np 989	9 000 4 790	3 000	> 50% np	N/DN chemical P	nt/349/739/28/3.9 nt/3.2/20/5.5/0.1	Vramsån River (Natura 2000, Unesco Biosphere Reserve “Vattenriket”)	-
Degeberga	np 216	2 000 950	1 328	-	Convent. N/DN chemical P	na/321/799/62/8.3 nt/1.5/15/13/0.16	Segesholmsån River	-
M-WWTPs in the model area of Lithuania (PE as BOD_7)								
Klaipėda	80 000 41 013	259 429 219 654	170 000	32% np	UCT	nt/353/704/79/8.9 2.0/3.8/44/9.6/0.28	Klaipeda Strait	organic carbon is used to support denitrification
Palanga	21,000 7 552	np 19 926	13 000	- np	A2O chemical P	222/163/np/41/7.5 3.9/2.9/2.4/5.3/0.37	Coastal waters of Baltic Sea Natura 2000	chemical treatment using Al_2O_3
Kretinga	5 160 3 576	np 18 151	18 127	25% np	AO	286/429/960/73/12 5.6/3.7/30/6.5/0.6	River Tenžė	
Nida	1 700 620	np np	1 697	-	AO	896/495/999/149/28 12/5.8/48/18/2.9	Curonian lagoon Curonian Spit National Park and biosphere polygon	
M-WWTPs in the model area of Germany (PE as BOD_5)								
Rostock	65 000*ds 96 000*rp 42 314	400 000 342 483	235 645	np np	1st bio-P-tank, pre-denitrification 2nd BIOFOR-N/DN	nt/np/np/np/np. nt/2.1/34/15/0.18	River Warnow	combined sewage system; *ds/*rp) dry season/remaining period;
Laage	3 600 880	20 000 12 658	4 516	63%. np	Convention. N/DN	nt/822/1 978/115/29 nt/np/np/np/np	River Recknitz,	
Krakow	1 450 630	7 500 6 209	3 964	36% np	Convention. N/DN	nt/656/1,259/112/17.2 nt/np/np/np/np	ditch draining into the river Nebel	

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