Pharmaceutical emissions from Scanian wastewater treatment plants in 2017

A development and collaborative project at Kristianstad University
- in cooperation with Skåne and six Scanian treatment plant operators

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Cover photo

Treated wastewater from Sankt Olof Treatment Plant in Österlen, Scania and its discharge pipe in Rörums Södra Å River. Photograph: E. Björklund.

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Summary

In April 2017 (following a Government assignment from 2016), the Swedish Environmental Protection Agency issued a report concerning advanced wastewater treatment for the separation of drug remnants and other undesired substances where they write that:

> *"The Swedish Environmental Protection Agency proposes that the Government have studies done of continued steps in a direction towards an introduction of advanced treatment beginning where the need is the greatest:*
>
> ***Step 1:*** *Investigate which wastewater treatment plants have the greatest need to introduce advanced treatment of drug remnants*
> ***Step 2:*** *Investigate what governance can lead to advanced treatment being introduced where the need is the greatest in a socioeconomically effective and suitable manner.*

The implemented LUSKA project shows how strategic collaboration between academia, municipalities and authorities is able to effectively map where measures primarily need to be applied to achieve a toxin-free environment in Sweden with living seas and water.

The project LUSKA (a Swedish acronym meaning 'to figure out' formed from the name LäkemedelsUtsläpp från SKånska Avloppsreningsverk - Pharmaceutical emissions from Scanian wastewater treatment plants) comprised six different participating wastewater treatment organisations, geographically distributed throughout the whole of the Scania region in Sweden (Skåne): Höganäs, Klippan, Höör/Hörby, Svedala, Kristianstad and Simrishamn. Sampling was done in April 2017 in four locations at each treatment plant. Three of these locations were chosen as suggested by the County Administrative Board of Skåne's supervisory guide: upstream, downstream and outlet water from the treatment plant. In addition, a fourth sample point was included consisting of inlet water to the treatment plants. In the study, a total of 21 out of 22 pharmaceuticals were analysed according to the Swedish Medical Products Agency's proposed substance watchlist from 2015. The analysis results from the eight treatment plants and associated recipients in the form of streams and lakes clearly shows that large amounts of pharmaceuticals end up in our surrounding Scanian waters every year. This takes place as a consequence of the wastewater treatment plants not being able to separate pharmaceutical emissions with existing technology based on activated sludge. The study showed that the eight treatment plants release at least 71 kg of pharmaceuticals every year to Scanian waters of these 21 substances alone. The major bulk of the measured substances were comprised of the blood pressure lowering drug metoprolol and the analgesic diclofenac. But even such substances as carbamazepine, losartan, naproxen and oxazepam occurred in significant concentrations in the wastewater. These substances include several pharmaceutical types and represent three general and relatively common illnesses: high blood pressure, inflammation and pain, and depression and anxiety. Based on the results in the LUSKA project, it can be estimated that when a treatment plant treats one million cubic metres (1,000,000 m^3) of wastewater, at the same time approximately 4 kg pass of the 21 drugs that the Swedish Medical Products Agency included on its watchlist. According to a rough estimate, including a majority of the Scanian wastewater treatment plants, this would mean that nearly 600 kg of drugs on the Swedish Medical Products Agency's proposed substances watchlist leak out from Scanian treatment plants every year. At the same time, it must be taken into account that these 21 substances only comprise a small part of the several hundred pharmaceutical substances used for the treatment of diseases. In all likelihood, one or more tonnes of drugs leak out into Scanian recipients annually. Measurements in lakes and streams show that even if the concentrations drop downstream of the plants, probably as a consequence of dilution, there are locales where the concentrations are remarkably high from a sustainability perspective.

Abbreviations

HaV = Havs- och Vattenmyndigheten [Swedish Agency for Marine and Water Management]
HKR = Högskolan Kristianstad [Kristianstad University]
LSS = Länsstyrelsen Skåne [County Administrative Board of Skåne]
RS = Region Skåne (regional authority for public transport and healthcare)
LMV = Läkemedelsverket [Swedish Medical Products Agency]
NVV = Naturvårdsverket [Swedish Environmental Protection Agency]

1. LUSKA project's origins and participants

LUSKA is the result of an effort made in 2016-2017 in the scope of funding granted by Region Skåne (RS) in 2015: *MILJÖVÅRDSFONDEN — Insatsområde friskt och livskraftigt hav och vatten i Skåne* [THE ENVIRONMENTAL CONSERVATION FUND – Application area of healthy and vital seas and waters in Scania]. The applicant was Kristianstad University (HKR) with Professor Erland Björklund as the contact person. The work was done by Senior Researchers Ola Svahn and Erland Björklund at HKR together with staff at six different wastewater treatment organisations in Scania: Höganäs Municipality, Klippan Municipality, Kristianstad Municipality, Mittskåne Vatten [Central Scania Water Utility] (Höör and Hörby municipalities), Simrishamn Municipality and Svedala Municipality. The geographic spread of the LUSKA project's participants is presented in **Image 1**.

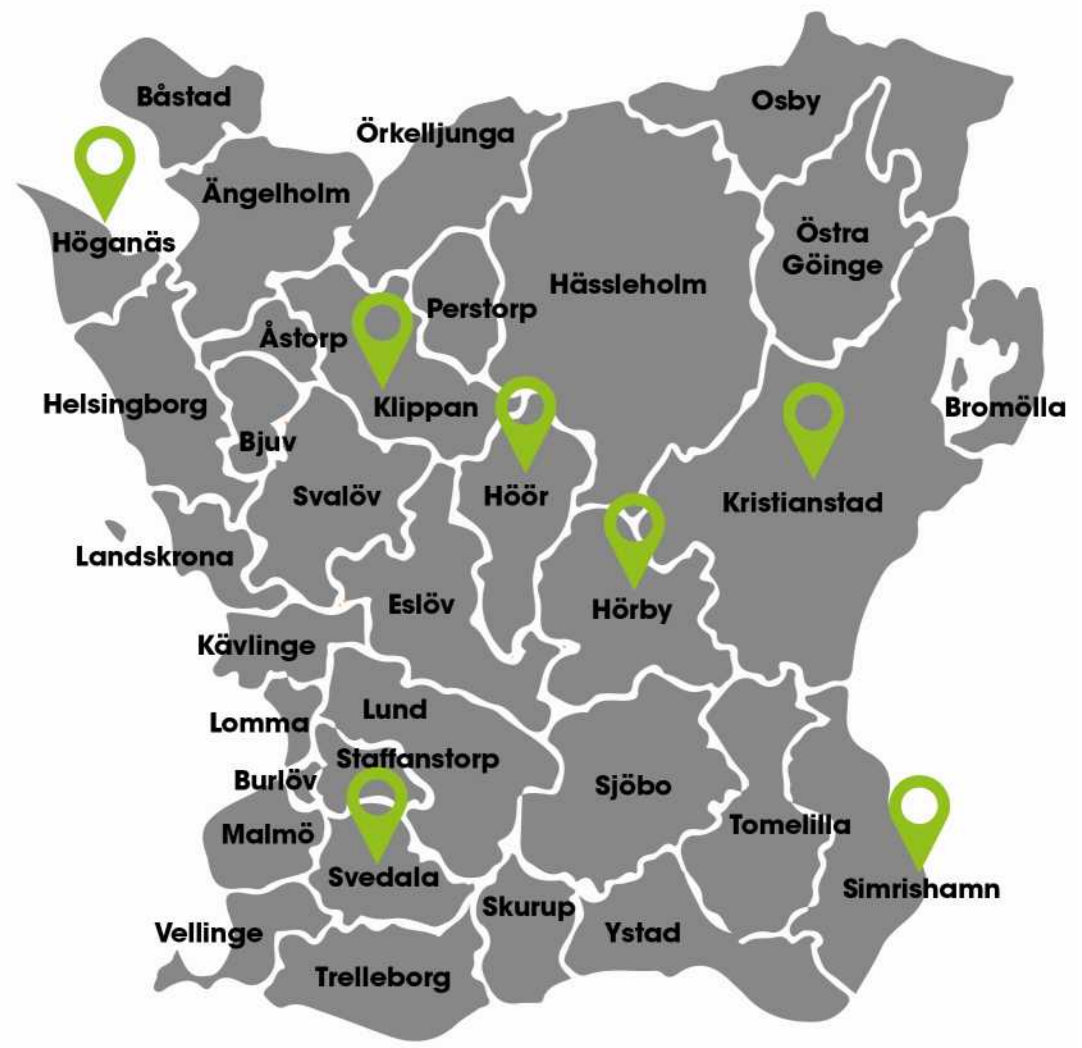


Image 1. *Participating organisations' geographic spread in Scania.*

2. Background and need

Pharmaceuticals, antibiotics and hormones, often called micropollutants, are found in all Swedish wastewater. Our wastewater treatment plants are not designed to remove the micropollutants from the water volumes. Several decades of research have led researchers today, the world over, agreeing that this continuous leakage of micropollutants from our treatment plants can cause stress on sensitive aquatic ecosystems. And even if the environmental risks are not fully established, there is a need to protect Scanian streams, lake systems, wetlands, the southern Baltic Sea, and Öresund from emissions of micropollutants. To resolve these problems, there is (1) a major need to map the emissions in order to (2) be able to take appropriate and concrete steps that reduce/prevent the leakage from the wastewater treatment plants. As previously mentioned, the LUSKA project includes treatment plants geographically spread throughout Scania, and treatment plants with connections to the Hanöbukten Bay, such as the treatment plants of the municipalities of Kristianstad and Simrishamn. The latter treatment plants are of national interest on the grounds of the extensive problems that exist with fish with ulcers and reduced catches in Hanöbukten.

On 29 October 2013, the Swedish Agency for Marine and Water Management (HaV) presented its report *Hanöbukten – Regeringsuppdrag [Hanöbukten – Government assignment]* [1](**Image 2**).

Image 2. *Swedish Agency for Marine and Water Management report "Hanöbukten – Government assignment 2013".*

Here, HaV writes that "*According to the knowledge available today, no single source, or single substance, has been able to be established to cause toxic effects in organisms in Hanöbukten's ecosystems. A number of knowledge gaps have been identified and a number of measures have been proposed, partly to prevent future problems, but also to reduce the risk of additive effects, for example.*" In addition, they write that "*There is a lack of knowledge to be able to draw any conclusions on possible cocktail effects in Hanöbukten*."

The mystery of Hanöbukten remains unsolved, and even if the project was not focused specifically on these problems, it might contribute a small piece of the puzzle on the way to clarifying Hanöbukten's problems. The structure of the LUSKA project is mainly intended to achieve improved water quality in Scanian recipients. Here, we want to emphasise how important it is that the work of mapping and in the long term resolving the emissions in Scanian wastewater must take place in close cooperation with staff at the municipal wastewater treatment plants to achieve the most effective measures possible. This is described below in the section "*Objective and steering documents*".

[1] Hanöbukten - Regeringsuppdrag. Havs- och vattenmyndighetens rapport 2013-10-20, 107 pages.

3. Objective and steering documents

In spring 2016, several Scanian wastewater treatment actors were invited to participate in the LUSKA project (see Section 4, *Invitation* below). In connection with this, the objective of the collaborative effort was presented where we intended to:

1. inform treatment plant staff about micropollutants in the wastewater, both how they are analysed and their occurrence, but also how work is currently being done nationally and in the EU on measures in the form of supplementary treatment technology.
2. carry out monitoring work in collaboration with the municipalities with regard to emissions of micropollutants from various treatment plants. Through access to the treatment plants, there is a possibility to make an assessment of the treatment plants' ability to reduce the micropollutants. By measuring both upstream and downstream of the treatment plants, the chemical load from the actual treatment plants to its recipient is mapped.
3. make use of the practical experience that exists among the participating treatment plants' staff and, based on produced measurement data, start a dialogue on both existing reduction of drug remnants and possible adjustments and improvements in the treatment plants that could reduce the emissions of pharmaceuticals.

Three steering documents, which were issued by different authorities in the past three years, guided the project work. These documents provide initial answers to two questions:

- WHERE should we measure?
- WHAT should we measure?

3.1 WHERE should we measure?

In 2014, the County Administrative Board of Skåne (LSS) issued its supervisory guide *Läkemedelsrester i avloppsvatten* [Drug remnants in wastewater][2], **Image 3**.

***Image 3.** The County Administrative Board of Skåne's supervisory guide "Drug remnants in wastewater 2014".*

In its supervisory guide, LSS writes that "*Pharmaceutical substances are not traditionally included in the sampling packages used for checks of outlet water. Within the scope of supervision, the issue should be made current of whether there is reason to increase the environmentally hazardous activities' self-inspection regarding pharmaceuticals (e.g. industries, livestock agriculture, waste treatment plants and wastewater treatment plants).*" In a later paragraph, LSS points out three sampling points. LSS writes "*The County Administrative Board of Skåne also considers that sampling of pharmaceutical substances shall take place with regard to outlet wastewater from treatment plants dimensioned for more than 200 pe and upstream and downstream of the treatment plant. This applies to both municipal treatment plants and private treatment plants in industrial parks, conference facilities, treatment centres and the like.*" These points are illustrated together with a fourth sampling point, at the wastewater treatment plant's inlet water, in **Image 4.**

[2] Supervisory guide from the County Administrative Board of Skåne (TVL-info 2014:12) - Läkemedelsrester i Avloppsvatten [Drug Remnants in Wastewater]; 6 page.

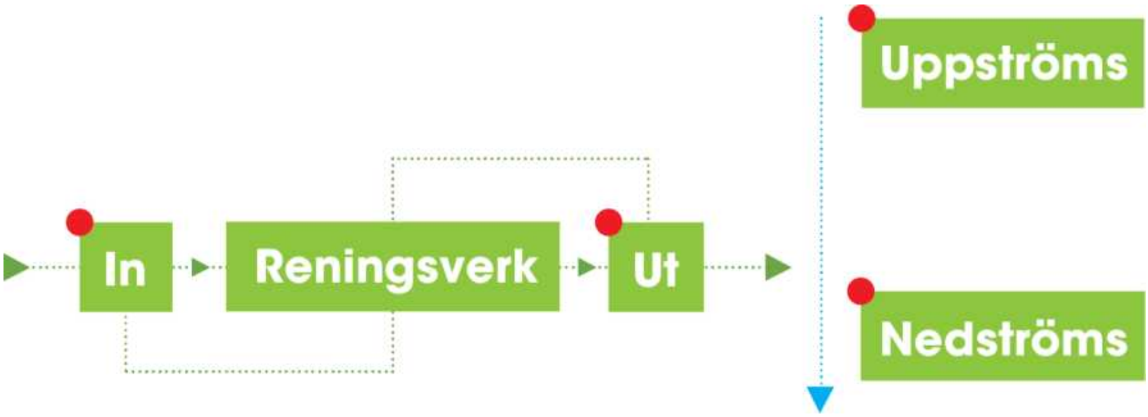
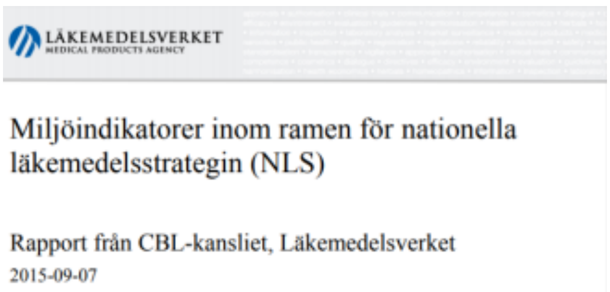


Image 4. *Three sampling points proposed by the County Administrative Board of Skåne and a fourth sampling point at the treatment plant's inlet water. (Reningsverk=Treatment plant, Ut=Out, Uppströms=upstream, Nedströms=downstream).*

In its supervisory guide, LSS does not state in detail how the samples should be taken or what type of samples should be taken. Nor does it state the sampling points' distance from the treatment plant upstream and downstream in the recipient. In the LUSKA project, sampling was done in cooperation with the treatment plant's staff based on their suggestions and experience.

3.2 WHAT should we measure?

Pharmaceuticals are a large group of substances and there are hundreds of approved active substances on the Swedish market. To be able to analyse and identify these pharmaceuticals in environmental tests, a large number of methods have been developed by researchers at various laboratories. Over the years, increasing numbers of substances have been added to the methods and today, they can comprise more than 100 substances. A consequence of this on one side is more information about the occurrence of pharmaceuticals in the environment and on the other is greater complexity, which in turn can lead to greater measurement uncertainty and higher costs in the analysis work. The comparability between different analyses can also be impeded if the same substances are not measured in the different methods. The need for coordinated national analyses has in recent years become increasingly clear and in 2015, the Swedish Medical Products Agency (LMV) issued its report *Miljöindikatorer inom ramen för nationella läkemedelsstrategin (NLS) [Environmental indicators in the scope of the national pharmaceuticals strategy (NLS)]*[3], **Image 5**.


LÄKEMEDELSVERKET
MEDICAL PRODUCTS AGENCY

Miljöindikatorer inom ramen för nationella läkemedelsstrategin (NLS)

Rapport från CBL-kansliet, Läkemedelsverket
2015-09-07

Image 5. *Swedish Medical Products Agency report "Environmental indicators in the scope of the national pharmaceuticals strategy (NLS) 2015".*

In LMV's report, several different indicators linked to the environment and the occurrence of pharmaceuticals was proposed, but one of these was highlighted in particular. LMV writes the following in its report: "*The working group considered the indicator "measure levels of pharmaceutical substances in environment" to be of the very highest priority. This is because, besides it being of major importance to monitor the development of drug remnants in the environment over time to evaluate the effect of implemented measures, the working group felt that there is considerable potential to optimise the use of the public resources through a better*

[3] Report from the Office of the Centre for Better Use of Pharmaceuticals, Swedish Medical Products Agency 07/09/2015 - Miljöindikatorer inom ramen för nationella läkemedelsstrategin (NLS) [Environmental indicators in the scope of the national pharmaceuticals strategy (NLS)]; 7 pages.

coordination of measurements in the environment. Many measurements have been taken historically by different public actors without any coordination." Furthermore, LMV writes that "*The working group's continued work came to focus on preparing proposals on substances that should be monitored in the environment, i.e. measurement of the occurrence of pharmaceutical substances in water, sludge, inlet and outlet water of treatment plants, biota, etc*."

The report ultimately recommends a list of 22 pharmaceuticals the environmental concentration of which is proposed to be monitored annually. The report also recommends that this list be sent to the Swedish Environmental Protection Agency (NVV) for further handling and that measurements of these 22 substances should supplement the measurements that NVV already does. In this context, it should be mentioned that some of the proposed substances are included in the *European Commission's watch list of substances for Union-wide monitoring in the field of water policy (EU) 2015/495*[4], the origins of which are not discussed further here.

For the LUSKA project, it was a major advantage that LMV pointed out the direction for which substances were of national interest. Focus could thereby be placed on developing the techniques and methods needed to be able to carry out these chemical analyses, which are briefly described below.

3.3 WHICH technique should be used for measurements?

Analysing pharmaceuticals in polluted water, which also most often occur at low to very low concentrations, requires special analysis methods based on an analysis technique called tandem mass spectrometry. Within the LUSKA project, a unique method was used to be able to analyse the proposed substances in the four sampling points. This flexible and robust method was developed by Ola Svahn and Erland Björklund in the chemical analysis laboratory **MoLab**, which is a joint effort between Kristianstad Municipality and HKR, and which was officially inaugurated in October 2015 in Krinova Incubator & Science Park, Kristianstad[5]. The analysis method was published in 2016 in the scientific journal *Journal of Chromatography B*[6] and in the thesis *Tillämpad miljöanalytisk kemi för monitorering och åtgärder av antibiotika- och läkemedelsrester i Vattenriket, Svahn 2016* [Applied environmental analytical chemistry for monitoring and measures regarding antibiotics and drug remnants in Vattenriket, Svahn 2016]. The method is validated according to an earlier method completed in 2007 by the United States Environmental Protection Agency (US EPA) for analysis of pharmaceuticals and personal hygiene products in water, soil, sediment and biomaterial using HPLC/MS/MS[7].

4. Invitation

Invitation 1 - Naturum Kristianstad Vattenrike April 2016

The first invitation to LUSKA was sent out in connection with Ola Svahn holding a presentation under the heading "*Analysis and measures regarding drug remnants in Kristianstad's aquatic environment"* for the majority of Scania's water utilities managers at Naturum, Kristianstads Vattenrike on 26 April 2016.

Invitation 2 - Krinova Kristianstad October 2016

For practical reasons, the sampling in autumn 2016 could not be carried out. Instead, Ola Svahn participated in a joint arrangement worked out and held by Kristianstad Municipality on 25 October 2016 at Krinova under the title "*How do we effectively remove drug remnants?*". Ola Svahn was invited to speak on the topic "*Drug remnants and environmental effects*" and share information about the need for: 1. mapping, 2. risks and 3. measures for pharmaceuticals and antibiotics in wastewater and the environment. Attendance at the meeting was good with around 80 participants from

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4 COMMISSION IMPLEMENTING DECISION (EU) 2015/495 of 20 March 2015 establishing a watch list of substances for Union-wide monitoring in the field of water policy pursuant to Directive 2008/105/EC of the European Parliament and of the Council; 3 pages.

5 http://www.hkr.se/nyheter/2015/ur-roken-steg-losningen-pa-miljoproblem-och-battre-diagnostik2/

6 Increased electrospray ionization intensities and expanded chromatographic possibilities for emerging contaminants using mobile phases of different pH, Journal of Chromatography B, 1033 (2016) 1-10, O. Svahn and E. Björklund

7 Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology Engineering and Analysis Division (4303T), 1200 Pennsylvania Avenue, NW, Washington, DC 20460, EPA-821-R-08-002, December 2007; 72 pages.

various municipalities in Scania, Blekinge, Halland and Småland.

After both of the meetings, six wastewater treatment organisations had registered for the LUSKA project. Höganäs Municipality, Klippan Municipality, Kristianstad Municipality, Mittskåne Vatten [Central Scania Water Utility] (Höör and Hörby municipalities), Simrishamn Municipality and Svedala Municipality.

5. Questionnaire, sampling, chemical analysis and follow-up meeting

In spring 2017, the various organisations were contacted prior to sampling. In connection with this, a questionnaire was also sent out to get general information on the size and treatment technology of the treatment plants. The sampling was done through visits by Ola Svahn, Erland Björklund and Jonatan Svahn (student intern at the MoLab) to the various treatment plants on 4-5 April 2017. Chemical analysis of the samples was done in MoLab during the month of April 2017.

Once all samples had been analysed and analysis data had been processed, a follow-up meeting was held at the Krinova Incubator & Science Park, Kristianstad, on 25 April 2017 with the participating wastewater treatment organisations and other interested organisations. In total, 20 people attended from eight organisations: Höganäs Municipality, Klippan Municipality, Kristianstad Municipality, Mittskåne Vatten [Central Scania Water Utility], Simrishamn Municipality, Svedala Municipality, Kristianstad University and the County Administrative Board of Skåne (**Appendix 1**). During this meeting, analysis data was compared and discussed with the participating organisations. Based on analyses done, survey input and the discussion at the meeting, work began on completing this report to be sent out to participating organisations in its final format in late autumn 2017.

6. Wastewater treatment plants

In total, eight wastewater treatment plants were included in the study. Two organisations, the municipalities of Kristianstad and Simrishamn, participated with two treatment plants each. The wastewater from both of these municipalities' treatment plants ends up in Hanöbukten, either indirectly through lakes and streams, or a direct release into the Baltic Sea. As presented below, the selected treatment plants cover a large number of possible scenarios and constitute a good foundation for model studies of the micropollutant emissions from Scania's wastewater treatment plants.

6.1 Plants geographic spread

The eight treatment plants have a large geographic spread across Scania and feed out into a large number of different run-off areas (see **Image 1**).

In the north west is the **Höganäs** Treatment Plant with discharge directly into Öresund's coastal area on the southern Kulla Peninsula. In inland north-west Scania is also the Klippan Treatment Plant, which has a discharge point in the Bäljane River, which runs on to the Rönne River and in turn feeds out to Ängelholm and Skälderviken (**Images 6 a-d**).

a **b** **c** **d**

Images 6 ***a-d.*** *At left, Höganäs Treatment Plant with discharge into Öresund (a, b). At right, Klippan Treatment Plant with discharge into Bäljane River (c, d). Photograph: E. Björklund.*

In south-west Scania, **Svedala** Treatment Plant was included with a discharge point in Sege River, which feeds into the southern Lommabukten north of Malmö. In central Scania, sampling was done in **Ormanäs** Treatment Plant that discharges its water in the northern part of Västra Ringsjön (**Images 7 a-d**).

a **b** **c** **d**

Images 7 ***a-d.*** *At left, Svedala Treatment Plant with discharge into Sege River (a, b). At right, Ormanäs Treatment Plant with discharge into Västra Ringsjön (c, d). Photograph: E. Björklund.*

In north-eastern Scania, two treatment plants were included, **Kristianstad** Treatment Plant and **Gärds Köpinge** Treatment Plant. Both of these treatment plants are located within the *Biosphere Area of Kristianstads Vattenrike*[8] and are linked to the Helge Å River drainage basin. Kristianstad Treatment Plant discharges its water in a 1500 m long excavated canal, which in turn feeds out into Hammarsjön. Helge Å River, which is Scania's largest river, has its inlet and outlet in

[8] http://www.vattenriket.kristianstad.se/index.php

Hammarsjön. Gärds Köpinge Treatment Plant has a discharge point in Vramsån River, which subsequently feeds into Helge Å River. Helge Å River then runs on eastwards towards Hanöbukten, with the largest mouth close to Yngsjö (Gropahålet) and a smaller mouth in Åhus Hamn, **Images 8 a-d.**

a **b** **c** **d**

Images 8 ***a-d.*** *At left, Kristianstad Treatment Plant with discharge into the canal and Hammarsjön (a, b). At right, Gärds Köpinge Treatment Plant with discharge into Vramsån River (c, d). Photograph: E. Björklund.*

In the south-eastern part of Scania, samples were taken from two treatment plants, **Sankt Olof** Treatment Plant and **Simrishamn** Treatment Plant. Both treatment plants are located in Österlen. Sankt Olof Treatment Plant discharges into Rörums Södra Å River, which then runs eastwards and feeds into Hanöbukten north of Vik. Simrishamn Treatment Plant discharges its treated water directly into Hanöbukten, **Images 9 a-d.**

a b c d

Images 9 ***a-d.*** *At left, Sankt Olof Treatment Plant with discharge into Rörums Södra River (a, b). At right, Simrishamn Treatment Plant with discharge into Hanöbukten (c, d). Photograph: E. Björklund.*

6.2 Treatment plants' size and flow

In addition to the geographic spread, the treatment plants' annual volumes of treated water vary and are presented by **Table 1. Image 10** also shows the treatment plants' basic design. Both **Table 1** and **Image 10** are in accordance with the responses received in the questionnaire that was sent out to each participant in connection with the invitation.

Table 1. *Presentation of the eight included treatment plants' operating parameters according to the responses returned by the participating organisations in the completed questionnaires. The value of zero ("0") means that the organisations stated this value, while the question marks ("?") mean that no value has been given or that uncertainty exists.*

Treatment plant	**Annual volume m3**	**Year**	**Hourly flow average m3/h**	**Max. Dim. PE**	**Actual number PE**	**Connected Residents Number**	**Industrial PE**	**Other Activities**	**Recipient**
Gärds Köpinge	76,538	2016	8.75	900	425	?	0	0	Vramsån River
Höganäs	3,075,792	2016	350	35,000	20,257	23,033	200	0	Öresund Sea
Klippan	1,366,560	2016	156	17,000	8,600	13,000	0	0	Bäljane Å River
Kristianstad	8,186,000	2016	958	205,000	118,300	52,000	64,000	?	Hammarsjön lake
Ormanäs	1,388,399	2016	184	13,500	3,782	9,000	?	2681	V. Ringsjön lake
Simrishamn	2,250,000	?	256?	87,000	23,000	?	6740	?	Hanöbukten Baltic Sea
Sankt Olof	200,000	?	?	1000	600	?	?	?	Rörums Södra Å River
Svedala	1,100,164	2016	125	18,500	9,800	12,000	?	Sturup	Sege Å River

Treatment plant	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Simrishamn	Mechanical, Cleaning grate, sandtrap	Chemical precipitation	Biological Anox/contact tanks	Reed beds	Final sedimentation		
Svedala	Inlet pumps, grating, sandtrap	2 x biolines with predenitrification	Intermediate sedimentation	Ferric chloride dosing	Final sedimentation	Sludge layer, gravitation thickener, centrifuge, liming of sludge (reserve sludge treatment is reed beds)	
Ormanäs	Monoscreen grating	Preliminary sedimentation	Activated sludge/ Predenitrification /Anox	Intermediate sedimentation	Chemical stage/precipitation PAX-XL 100	Floration tanks	Sand filter
Klippan	Stair grating	Preliminary sedimentation	Activated sludge/ Predenitrification	Simultaneous precipitation with iron sulphate	Sedimentation		
Höganäs	Step screen	Preliminary sedimentation	Activated sludge process, Predenitrification, bio-p	Post precipitation with polyaluminium chloride, sedimentation	Downstream sand filter		
Gärds Köpinge	Mechanical cleaning: Spiral screen	Activated sludge/ Aeration (pipe aerator)/ Sedimentation	Chemical precipitation with $FeCl_3$/Flocking	Sedimentation	CRV Kristianstad		
Kristianstad	Stair grating	Preliminary sedimentation	Activated sludge/ Predenitrification/Krauss process/ Sedimentation	Activated sludge/ Predenitrification/ Sedimentation	Precipitation with $FeCl_3$/ Flocking	Slat sedimentation	Downstream sand filter

Image 10. *Presentation of the eight included treatment plants' design according to the responses returned by the participating organisations in the completed questionnaires.*

The treated volume of water in the treatment plants varies from around 77,000 m^3, in the smallest treatment plant in Gärds Köpinge, to more than 8,000,000 m^3 in the Kristianstad Treatment Plant. The relative size of the treatment plants based on annual volumes of treated water, based on Gärds Köpinge treatment plant (value = 1) thereby varies with a factor over 100 which is seen in **Figure 1**.

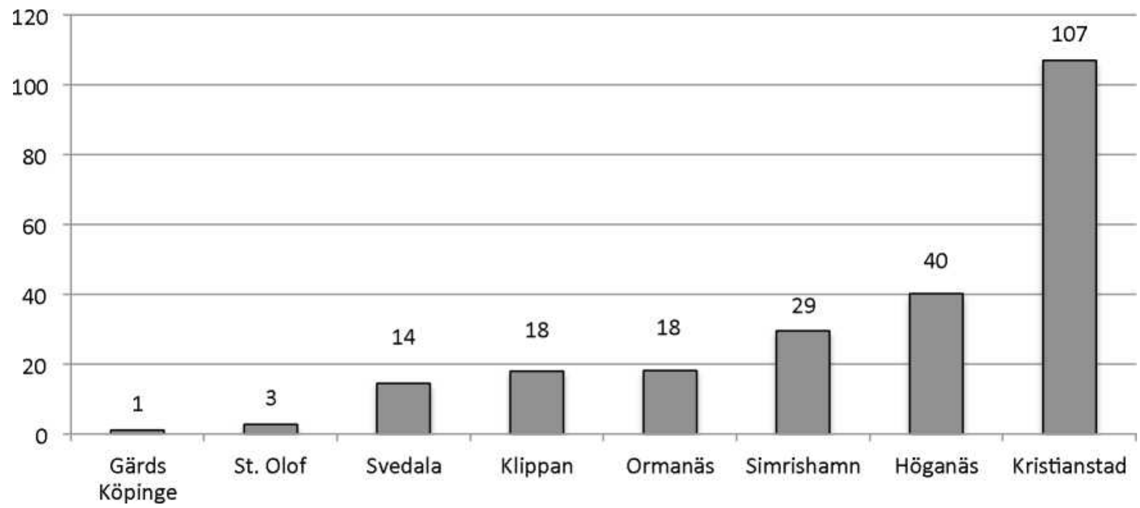

Figure 1. *The relative size of the treatment plants based on annual volumes of treated water based on Gärds Köpinge treatment plant with the value 1 corresponding to approx. 77,000 m^3 treated water/year.*

The hourly flow of water as an average in m^3/h also varies widely, ranging from Gärds Köpinge at 8.75 m^3/h, to Kristianstad at 958 m^3/h; a factor of 109. The actual number of PE is also very different, from 425 PE in Gärds Köpinge to 118,300 PE in Kristianstad Treatment Plant; a factor of 278. Kristianstad Treatment Plant like Simrishamn Treatment Plant stands out with a large component of industrial water. The treatment plants included therefore represent a broad scenario of treatment plant types.

7. Results of pharmaceutical analyses

In total, 21 of 22 substances on the Swedish Medical Products Agency's list in eight different treatment plants.

7.1 Chemical emissions of pharmaceuticals from eight treatment plants in concentrations (ng/L)

The recipients' chemical loads, expressed as outlet concentrations of pharmaceuticals, from all eight treatment plants are presented in **Table 2.** The treatment plants and the pharmaceuticals are listed in alphabetical order, but are not discussed in this order. In the table, the average emission concentration of each substance has been calculated as the average of the emissions from all eight treatment plants. This provides an initial picture of which substances have the highest concentrations in Scanian wastewater and is shown in **Figure 2.** The two with the highest average concentration were metoprolol and diclofenac with concentrations of over 500 ng/L, or 0.5 pg/L.

Table 2. Outlet concentrations in ng/L of 21 pharmaceuticals from eight Scanian wastewater treatment plants. Blue values indicate the treatment plant with the lowest outlet concentration, while red values indicate the treatment plant with the highest outlet concentration of the respective substance. In this table, the treatment plants and the pharmaceuticals are listed in alphabetical order, but are not discussed in this order.

	Gärds Köpinge	Höganäs	Klippan	Kristianstad	Ormanäs	Simrishamn	Sankt Olof	Svedala	Average conc.	Stdev	RSD (%)
Ciprofloxacin	0	0	0	0	0	0	0	0	**0**	0	
Citalopram	120	93	135	80	164	110	104	217	**128**	44	35
Clarithromycin	0	56	101	24	82	29	3	213	**64**	70	111
Diclofenac	579	594	707	746	442	685	569	1117	**680**	201	30
Erythromycin	1	53	166	215	12	113	3	640	**150**	213	142
Estrone	18	1	1	3	63	7	4	7	**13**	21	161
Fluconazole	3	59	52	105	71	24	17	53	**48**	33	68
Ibuprofen	0	0	92	0	1158	613	124	107	**262**	415	158
Carbamazepine	139	442	439	470	529	233	601	699	**444**	183	41
Ketoconazole	1	2	6	0	4	2	6	6	**3**	2	72
Levonorgestrel	0	0	0	0	0	0	0	0	**0**	0	
Losartan	386	344	274	217	83	673	497	921	**424**	268	63
Metoprolol	692	954	979	714	843	1016	943	1430	**946**	230	24
Methotrexate	0	0	0	0	0	0	0	0	**0**	0	
Naproxen	145	378	290	119	266	379	1430	304	**414**	421	102
Oxazepam	95	323	401	475	349	328	472	370	**352**	119	34
Sertraline	19	18	40	4	47	8	27	32	**24**	15	62
Sulfamethoxazole	0	238	118	208	173	51	0	281	**134**	109	81
Tramadol	190	145	187	208	118	81	94	151	**147**	47	32
Trimethoprim	6	95	78	29	64	33	1	107	**52**	40	78
Zolpidem	3	3	2	3	1	1	2	4	**2**	1	45

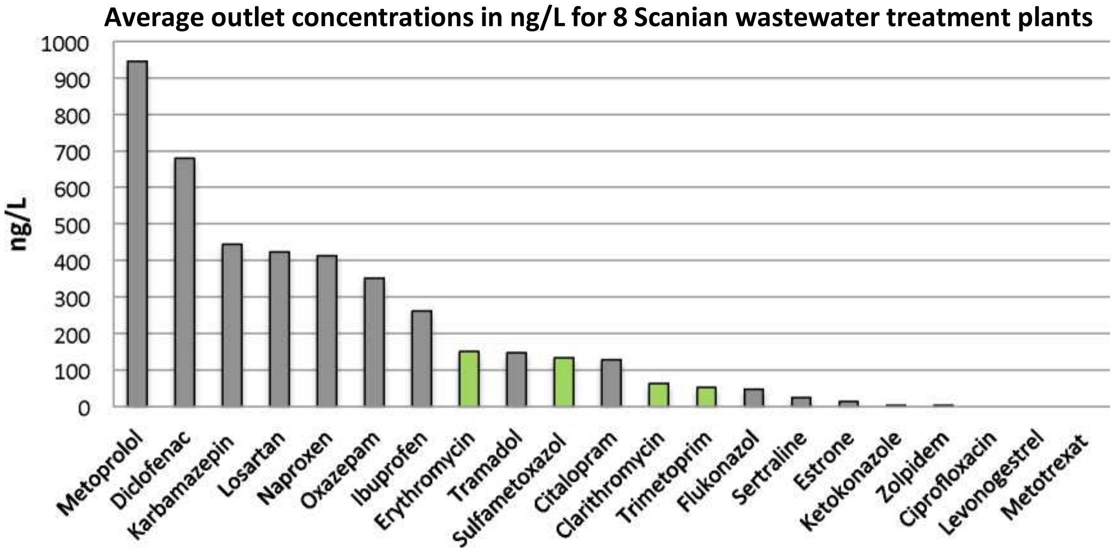

Figure 2. *Average of the concentrations (ng/L) of the 21 analysed pharmaceuticals in outlet water from eight Scanian wastewater treatment plants. Antibiotics are marked in green except ciproflaxacin that was not found in measurable concentrations. The values are found in Table 2.*

7.1.1 Metoprolol

Metoprolol is a so-called beta blocker that blocks the beta receptors in the body, and is used against high blood pressure and angina pectoris. Metoprolol is used by large population groups and showed the highest average of all substances at 946 ng/L, or approx. 1 µg/L (**Figure 2**). The variation between the various treatment plants is small. Gärds Köpinge with an actual number of PE of 425 had the lowest concentration equivalent to 692 ng/L, while Svedala with an actual number of PE of 9800 showed the highest value at 1430 ng/L (**Table 2**). The factorial difference between the highest and lowest concentration is only 2.1 (1430/692=2.1). The concentrations found are also very close to those measured in an earlier Swedish study from 2010 done by Stockholm Vatten[9] where the Henriksdal treatment plant had an outlet concentration of 1161 ng/L (RSD = 53%), while Bromma treatment plant had 1320 ng/L (RSD = 68%). Both as an average of multiple analyses. This document will below be called *Stockholm Vatten 2010*. A broader palette of Swedish treatment plants is in the Swedish National Screening Programme, reported in 2011[10]. This document will below be called *National Screening 2011*. No Scanian treatment plants were included in this screening in 2011. In *National Screening 2011*, results are shown from outlet concentrations for treatment plants from the four cities Skövde, Stockholm, Uppsala and Umeå where water from each treatment plant was analysed three times. A comparison for metoprolol between the eight Scanian treatment plants and the four Swedish cities' treatment plants is seen in **Figure 3.** The concentrations for the Scanian treatment plants is on a par or somewhat below the results from the national screening.

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9 Stockholm Vatten (2010) Läkemedelsrester I Stockholms vattenmiljö —Förekomst, förebyggande åtgärder och rening av avloppsvatten [Drug remnants in Stockholm's water environment - occurrence, preventive measures and treatment of wastewater], 2010; 140 pages.

10 IVL (201) Results from the Swedish National Screening Programme 2010. Subreport 3. Pharmaceuticals. Swedish Environ Mental Research Institute. IVL Report B2014, December 2011; 56 pages

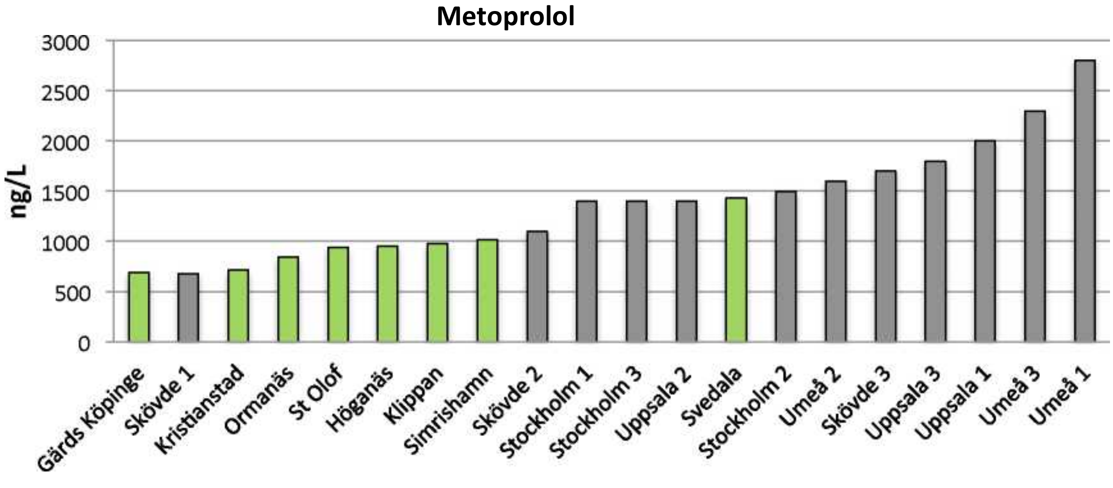


Figure 3. *Measured concentrations (ng/L) of metoprolol in outlet water from the eight Scanian treatment plants and in the Swedish National Screening Programme reported in 2011 for the four cities Skövde, Stockholm, Uppsala and Umeå. These four treatment plants were analysed three times each and are indicated by 1, 2 and 3. For clarity, the Scanian treatment plants' concentrations are marked in green.*

7.1.2 Diclofenac

Diclofenac belongs to the group of anti-inflammatory NSAID medicines (non-steroidal anti-inflammatory drugs) and has a broad area of use including migraines, tooth aches, menstrual pains and muscle and joint pain in rheumatic diseases. Diclofenac showed the second highest concentrations with an average of 680 ng/L (approx. 0.7 pg/L). The variation between the treatment plants is small for diclofenac as well. Ormanäs treatment plant had the lowest concentration at 442 ng/L while Svedala had the highest concentration at 1117 ng/L. The factorial difference between the highest and lowest concentration is only 2.5.

The concentrations of diclofenac can be compared with *Stockholm Vatten 2010* where Henriksdal treatment plant had an outlet concentration of 288 ng/L (RSD = 36%), while Bromma treatment plant had 257 ng/L (RSD = 32%). A comparison with the *National Screening 2011* is show in **Figure 4**.

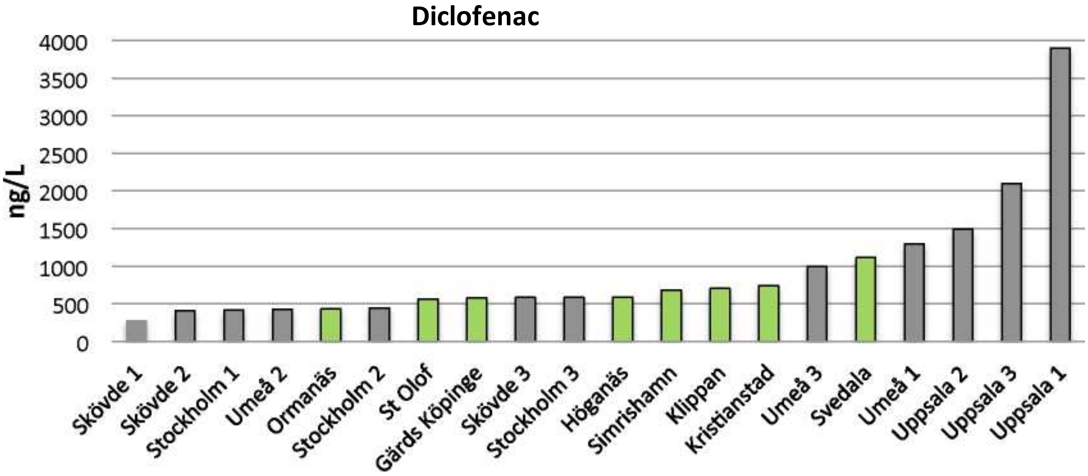
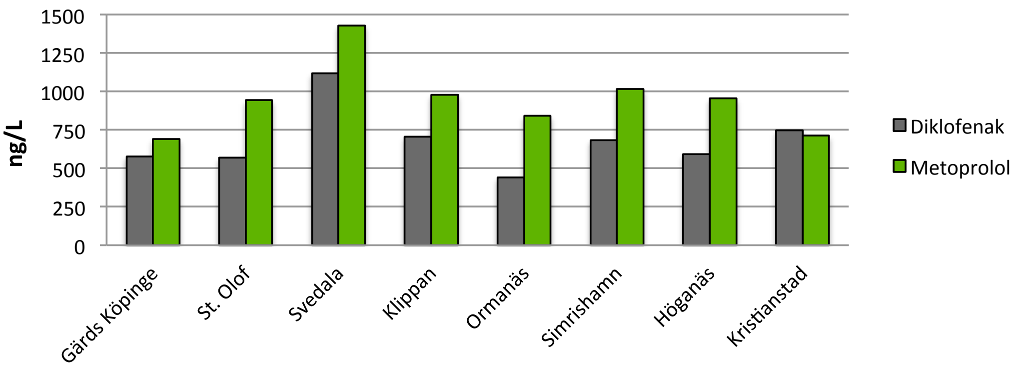


Figure 4. *Measured concentrations (ng/L) of diclofenac in outlet water from the eight Scanian treatment plants and in the Swedish National Screening Programme reported in 2011 for the four cities Skövde, Stockholm, Uppsala and Umeå. These four treatment plants were analysed three times each and are indicated by 1, 2 and 3. For clarity, the Scanian treatment plants' concentrations are marked in green.*

For diclofenac, the Scanian values are somewhat more centred compared with the *National Screening 2011*, where the latter has both lower and higher reported concentrations.

A comparison of how the concentrations of metoprolol and diclofenac track in the eight Scanian treatment plants is shown in **Figure 5 a**. There, the similarities can be clearly seen in the measured concentrations in outlet wastewater for metoprolol and diclofenac. The treatment plants are listed in order of size as per **Figure 1** above. In Figure 5 b, one can also see that the treatment plants' size does not seem to have any impact on their ability to remove metoprolol and diclofenac.



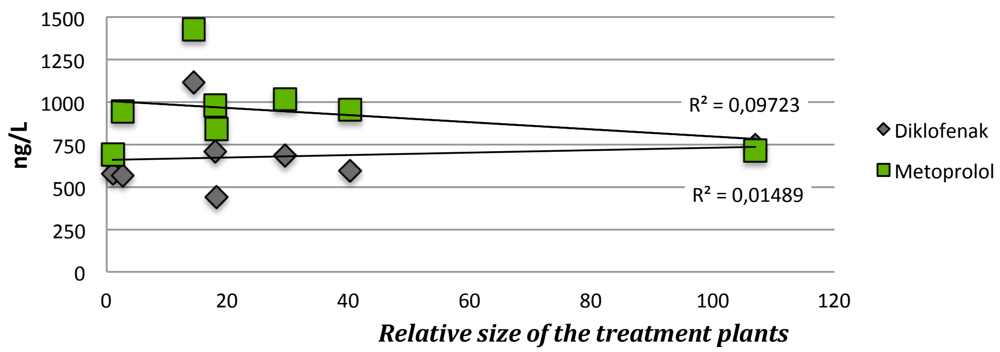


Figure 5 a and 5 b. *Measured concentrations (ng/L) of metoprolol and diclofenac in outlet water from the eight Scanian treatment plants (Figure 5a). Metoprolol had the highest average value of the studied substances (946 ng/L) followed by diclofenac (680 ng/L) which is seen in Table 2. The treatment plants are listed in order of size as per Figure 1 above. Figure 5 b shows outlet concentrations in relation to the treatment plants' relative size as per Figure 1.*

7.1.3 Carbamazepine, losartan, naproxen, oxazepam and ibuprofen

These five substances include several pharmaceutical types that largely represent three general and relatively common illnesses: high blood pressure, inflammation and pain, and depression and anxiety. As seen in **Table 2** and **Figure 2**, the average of the concentrations of these pharmaceuticals was in the range 200-500 ng/L (0.2-0.5 µg/L).

Carbamazepine is used for epilepsy and alcohol abstinence and occurs in all treatment plants in concentrations between 139 ng/L (Gärds Köpinge) and 699 ng/L (Svedala) with an average of 444 ng/L. The factorial difference between the highest and lowest is 5.0 and somewhat higher than for metoprolol and diclofenac. Carbamazepine occurs in all treated waters. Results from *Stockholm Vatten 2010* showed that the Henriksdal treatment plant had a concentration of 373 ng/L (RSD = 32%), while Bromma treatment plant had 305 ng/L (RSD = 35%). The concentrations of carbamazepine in *National Screening 2011* varied between 460-1100 ng/L for the four cities included. The Scanian values are in line with previously measured concentrations.

Losartan is a blood pressure-lowering medicine and has an average that is close to carbamazepine: 424 ng/L. The variation in occurrence is, however, somewhat higher, with Ormanäs at a low of 83 ng/L and Svedala at a high of 921 ng/L. Altogether, this yields a factorial difference of 11 for losartan. Results from *Stockholm Vatten 2010* showed that the Henriksdal treatment plant had a concentration of 204 ng/L (RSD = 48 %), while Bromma treatment plant had 187 ng/L (RSD = 48 %). Losartan was not analysed in the *National Screening 2011*.

Like diclofenac, naproxen belongs to the anti-inflammatory NSAID drugs and has an average just below losartan: 414 ng/L. The spread in concentration is also very similar to losartan with a low of 119 ng/L in Kristianstad and a high of 1430 ng/L in Sankt Olof. This means that the factorial difference for naproxen is 12. The naproxen value for Sankt Olof stands out somewhat compared with the other treatment plants in the Scanian study as the highest value is Simrishamn with a concentration of 379 ng/L. The average and factorial difference without Sankt Olof thereby drops to 269 ng/L and 3.2. S*tockholm Vatten 2010* showed that the Henriksdal treatment plant had a concentration of 476 ng/L (RSD = 84 %), while the Bromma treatment plant had 565 ng/L (RSD = 46 %). The concentrations of naproxen in *National Screening 2011* varied between 26-490 ng/L for the four cities included.

Oxazepam belongs to the group of benzodiazepines and is an antidepressant that is used for anxiety and depression. Oxazepam is also classed as a narcotic and has received attention for its effect on perch, which demonstrate behaviour changes when subjected to oxazepam. The average of oxazepam's measured concentrations was 352 ng/L. The lowest concentration was shown in Gärds Köpinge (95 ng/L) and the highest in Kristianstad 475 ng/L. This yielded a factorial difference of 5.0 for oxazepam. Gärds Köpinge stands out in this context where the other treatment plants were in the range 323-475 ng/L and had a factorial difference of only 1.5. S*tockholm Vatten 2010* showed that the Henriksdal treatment plant had a concentration of 324 ng/L (RSD = 49 %), while the Bromma treatment plant had 190 ng/L (RSD = 31 %). A comparison between the eight Scanian treatment plants and the results for the four cities Skövde, Stockholm, Uppsala and Umeå in *National Screening 2011* is shown in **Figure 6.**

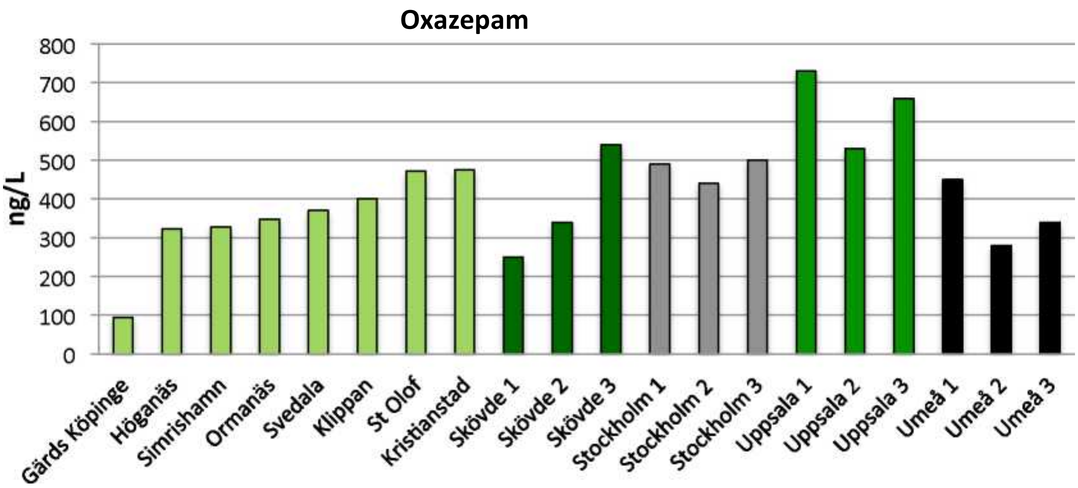


Figure 6. *Measured concentrations (ng/L) of oxazepam in outlet water from the eight Scanian wastewater treatment plants (at left in the figure). Oxazepam had an average of the concentrations of 352 ng/L which is seen in Table 2. From the figure, it is also apparent that Gärds Köpinge has a relatively low concentration. The eight Scanian treatment plants are listed in order of size as per Figure 1 above. At right in the figure are the results from the National Screening 2011 with three measurement points from each city individually: Skövde, Stockholm, Uppsala and Umeå.*

The measured concentrations of oxazepam in the LUSKA project agree well with earlier Swedish studies.

Ibuprofen is a third anti-inflammatory NSAID drug (besides diclofenac and naproxen) that is sold over-the-counter and has widespread use. The average of ibuprofen's measured concentrations was 262 ng/L, but with very large differences in occurrence. In three of the treatment plants, the substance could not be detected at all (Gärds Köpinge, Höganäs and Kristianstad), while Ormanäs had a concentration above 1 μg/L (1158 ng/L). Results from *Stockholm Vatten 2010* showed that the Henriksdal treatment plant had a concentration of 42 ng/L (RSD = 136 %), while Bromma treatment plant had 80 ng/L (RSD = 108 %). The concentrations of ibuprofen in *National Screening 2011* varied relatively widely, just like the Scanian treatment plants, with concentrations between 42-990 ng/L for the four cities included.
All five substances in this section can be noted to contain concentrations that are in parity with earlier Swedish studies. Nor was there any identifiable relationship between the treatment plants' size (**Figure 1**) and the levels of the emission concentrations.

7.1.4 Seasonal variation of six pharmaceutical concentrations (ng/L) at the Kristianstad Treatment Plant

Based on analysis data above for the six substances with the highest concentration (metoprolol, diclofenac, carbamazepine, losartan, naproxen and oxazepam), virtually all of the substances occur in all studied treatment plants in concentrations that vary by a factor of 2-12, depending on the substance. To get an idea of how the substances vary over time, a parallel study was done at the Kristianstad Treatment Plant, where samples were taken during all four seasons of the year 2016-2017 (n=13). The results for these six pharmaceuticals are shown in **Table 3.** The variation over the year is illustrated for metoprolol and diclofenac in **Figure 7.**

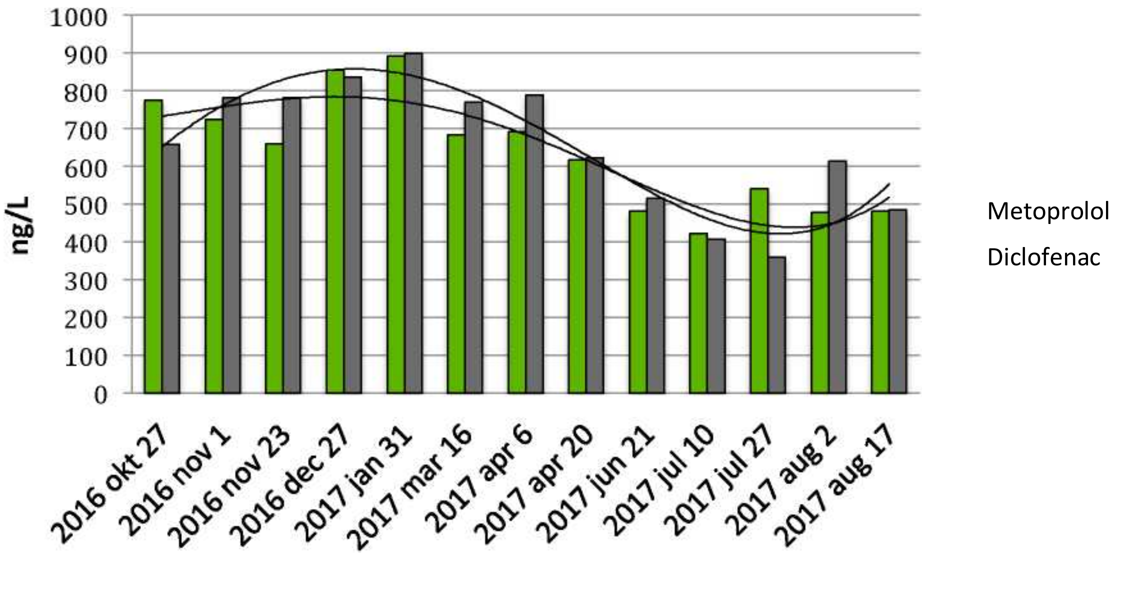


Figure 7. *Measured concentrations (ng/L) of metoprolol and diclofenac in outlet water from the Kristianstad Treatment Plant. Metoprolol and diclofenac has seasonal concentrations of 638 and 655 ng/L which is seen in Table 3. From the figures, it is apparent that a tendency to seasonal variation occurs in emitted concentrations.*

Figure 7 shows clearly that both the substances are emitted regardless of season. For both the substances, a tendency is seen that the concentrations are highest in December and January, but drop slightly in June and July to then turn upwards again. For all six substances, similar tendencies were observed.

Another observation is that the average annual concentration for metoprolol is 638 ng/L (RSD = 23 %, n=13) (**Table 3**). In the LUSKA project, all samples were taken on 4-5 April for all eight treatment plants. The average of the concentrations for eight treatment plants in the month of April was 946 ng/L (RSD = 24 %, n=8) (**Table 2**). In addition, this can be compared with the metoprolol concentration in the month of April for the Kristianstad Treatment Plant in the

LUSKA project of 714 ng/L (n=1). The month of April's average of the concentrations in the LUSKA project thereby somewhat well reflects the annual average concentration for the Kristianstad Treatment Plant. In the same way, the month of April's single metoprolol value in the Kristianstad Treatment Plant is a good indicator for the annual average concentration. **Figure 8** presents the annual average concentration of the six substances discussed above for the Kristianstad Treatment Plant (n=13) and the average of the substances' concentrations in April for all eight treatment plants (n=8) in LUSKA, as well as the substances' concentrations in the month of April from the Kristianstad Treatment Plant (n=1).

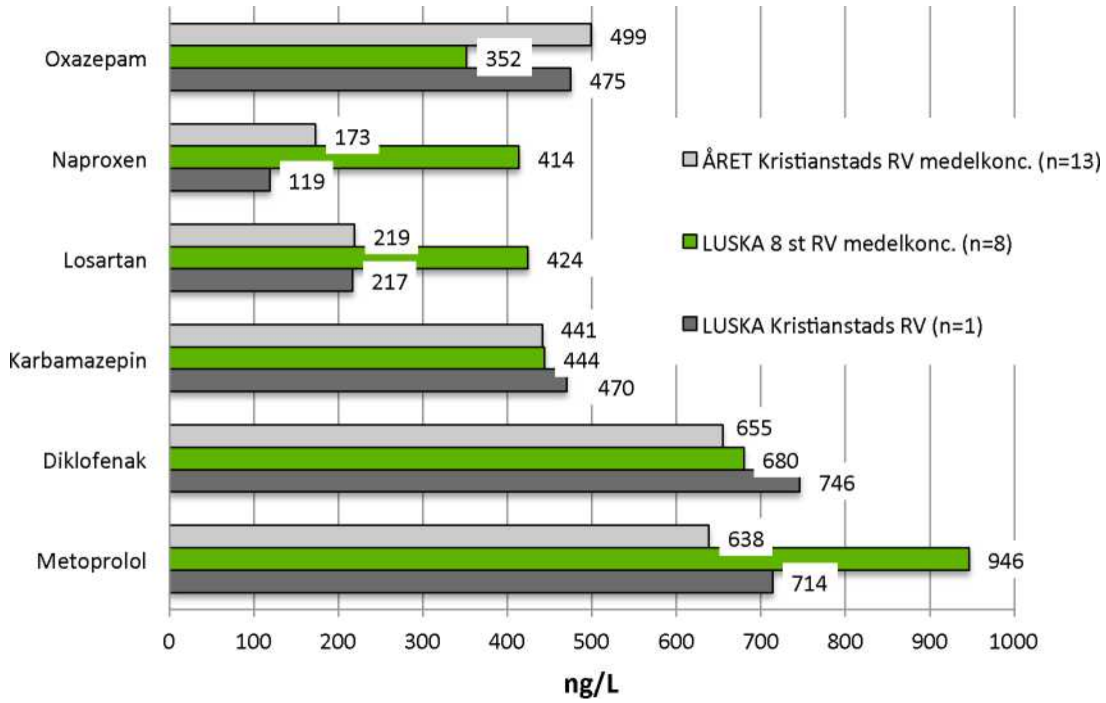


Figure 8. *Comparison of the annual average concentration (YEAR) in ng/L for the Kristianstad Treatment Plant (n=13, Table 3) and the average of concentrations in ng/L for eight treatment plants (RV) in the month of April (n=8, Table 2), as well as individual concentrations for the Kristianstad Treatment Plant (n=1, Table 2).*

The similarities seen for metoprolol, between the average of the concentrations in the month of April for eight treatment plants (n=8) and the annual average concentration at the Kristianstad Treatment Plant (n=13), were most distinct for diclofenac, carbamazepine and oxazepam, but somewhat less distinct for losartan and naproxen, **Figure 8**.

Table 3. *Measured concentrations of ng/L of 6 pharmaceuticals in outlet water from the Kristianstad Treatment Plant at different seasons in 2016-2017*

	2016 27 Oct.	**2016 1 Nov.**	**2016 23 Nov.**	**2016 27 Dec.**	**2017 31 Jan.**	**2017 16 Mar.**	**2017 6 Apr.**	**2017 20 Apr.**	**2017 21 June**	**2017 10 July**	**2017 27 July**	**2017 2 Aug.**	**2017 17 Aug.**	**Ave. conc. (n=13)**	**Stdev**	**RSD %**
Metoprolol	774	724	659	855	892	684	691	616	481	421	541	478	481	638	145	23
Diclofenac	658	781	781	836	898	770	789	622	515	407	359	614	485	655	165	25
Carbamazepine	447	552	454	470	529	367	472	360	461	417	395	385	431	441	56	13
Losartan	326	330	261	256	207	221	212	213	153	119	91	306	153	219	73	33
Naproxen	476	204	253	376	85	269	132	144	44	41	32	177	20	173	135	78
Oxazepam	561	589	535	544	551	501	549	474	451	471	389	406	472	499	59	12

7.1.5 Antibiotics

Antibiotics as a group are of particular interest nationally and internationally due to the formation of resistance. This study included a total of five antibiotics: ciprofloxacin, clarithromycin, erythromycin, sulfamethoxazole and trimethoprim, the values of which are shown in **Table 2**, and are indicated by green in **Figure 2**.

Ciprofloxacin is an antibiotic that belongs to the group of quinolones and is a broad-spectrum antibiotic. The substance is effective against many different types of bacteria. Ciprofloxacin was not found in any outlet wastewater, which is mainly due to this compound largely being adsorbed to the sludge. In previous studies, we and other research teams have found it in several hundred up to a few thousand µg/kg sludge (*Stockholm Vatten 2010*). Results from *Stockholm Vatten 2010* also show low concentrations out from the Henriksdal treatment plant at 20 ng/L (RSD = 50 %) and Bromma treatment plant at 40 ng/L (RSD = 44 %). The concentrations of ciprofloxacin in *National Screening 2011* varied between 0-65 ng/L for the four cities included.

Clarithromycin and *erythromycin* are two so-called macrolides that are included in the *European Commission's watchlist* (see footnote 4 above). They are similar in their chemical structure and are used to treat various types of bacterial infections. Both of them are found in wastewater. The concentrations of clarithromycin varied between 0-213 ng/L while erythromycin varied between 1-640 ng/L. Clarithromycin was not analysed by *Stockholm Vatten 2010*, but however erythromycin was and was found in concentrations of 236 ng/L (RSD = 67 %), compared with a Scanian average of 151 ng/L. However, erythromycin was only found in very low concentrations (< 3 ng/L) in the two smallest treatment plants in Scania (Gärds Köpinge and Sankt Olof) which is discussed in more detail below. If both of these treatment plants are removed from the average calculation, a new average is obtained for Scania of 200 ng/L, which is very similar to those from *Stockholm Vatten 2010*. In *National Screening 2011*, the concentrations for clarithromycin varied in the range 0-780 ng/L and erythromycin between 53-530 ng/L, so in the same range as the Scanian treatment plants, but with a broader range.

Sulfamethoxazole and *trimethoprim* are administered as combination preparations. Sulfamethoxazole is an antibiotic in the group of sulphonamides and inhibits the synthesis of folic acid in bacteria. Trimethoprim is also a folic acid antagonist. The concentrations of the combination preparation sulfamethoxazole and trimethoprim vary between a few ng/L up to 281 ng/L with averages of 134 ng/L and 52 ng/L for sulfamethoxazole and trimethoprim. Sulfamethoxazole and trimethoprim were both found by *Stockholm Vatten 2010* in Henriksdal treatment plant at 60 ng/L (RSD = 67 %), and 35 ng/L (RSD = 45 %), respectively, while Bromma reported concentrations of 52 ng/L (RSD = 54 %) and 186 ng/L (RSD = 29 %), respectively. In *National Screening 2011,* the range for sulfamethoxazole was 30-290 ng/L and for trimethoprim 60-510 ng/L. The emissions from Scanian treatment plants are in line with *Stockholm Vatten 2010* but somewhat lower than *National Screening 2011*.

None of the analysed antibiotic substances showed any relationship between the concentration and the size of the treatment plant. However, a very tangible difference could be seen between the two smallest treatment plants (Gärds Köpinge and Sankt Olof) and the other treatment plants (**Figure 9**).

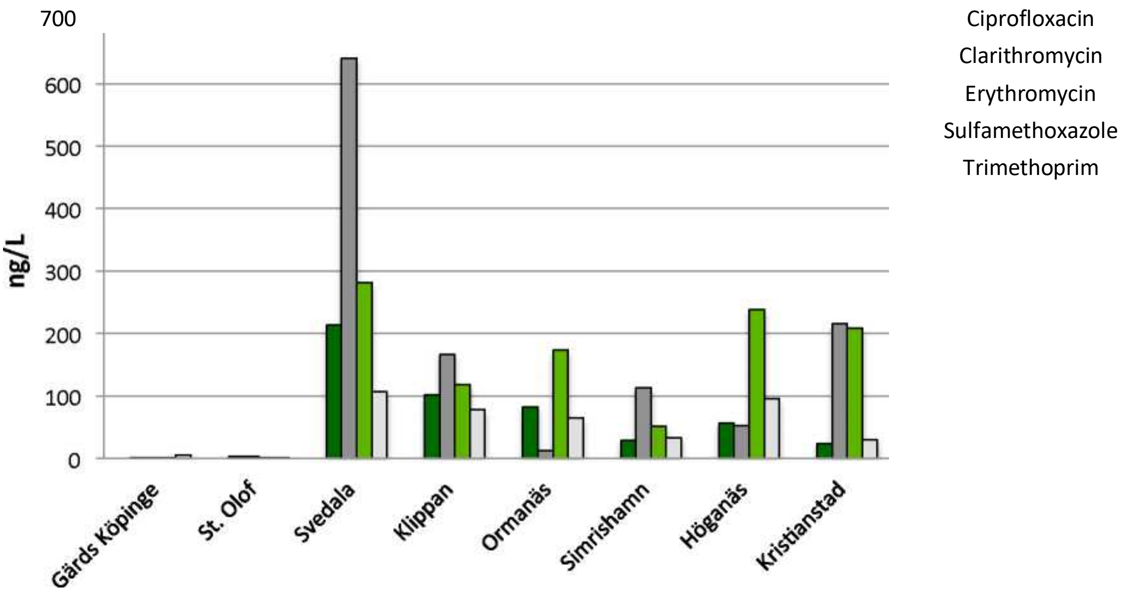


Figure 9. *Measured concentrations (ng/L) of five antibiotics (ciprifloxacin, clarithromycin, erythromycin, sulfamethoxazole and trimethoprim) in outlet water from the eight Scanian treatment plants. The treatment plants are listed in order of size as per Figure 1 above.*

Both of the smaller treatment plants have virtually no measurable concentrations of antibiotics. The size of both of these treatment plants is also significantly smaller than the others, with a factor of 5-30 compared with the next three in order (see **Figure 1** above). The number of PE in Gärds Köpinge and Sankt Olof is only 425 and 600, respectively A possible explanation for the occurrence of antibiotics being low may be that antibiotics are simply not taken as regularly as e.g. heart medication and medicines against pain, but rather as specific courses of treatment. Small treatment plants then very rarely have enough parallel treatments under way for it to be reflected in the wastewater.

7.1.6 Tramadol, citalopram, fluconazole and sertraline

The four medicines tramadol, citalopram, fluconazole and sertraline occurred in the concentrations 147, 128, 48, and 24 ng/L, respectively, calculated as averages for the eight treatment plants.

Tramadol belongs to the group of opioids and is classed as a narcotic in Sweden, while *citalopram* is an anti-depressant of the type SSRI. Both of these substances had a low factorial difference of only 2.6 and 2.3, respectively (**Table 2**).

Tramadol occurred in concentrations between 81-208 ng/L and an average of the concentrations of 147 ng/L, which differs slightly from *Stockholm Vatten 2010* where Henriksdal and Bromma treatment plants had concentrations of 571 ng/L (RSD = 49 %) and 474 ng/L (RSD = 50 %). *National Screening 2011* showed even higher concentrations in the range 730-3000 ng/L. Here, it should be emphasised that tramadol was one of the substances that showed the largest measurement uncertainty between the various laboratories included in the inter-calibration study done in MoLab by Ola Svahn and Erland Björklund in spring 2017 together with four Swedish and one Danish analysis laboratory on behalf of the Swedish Agency for Marine and Water Management. Details regarding this will be available in the report being compiled[11].

Citalopram was measured in concentrations between 80-217 ng/L in Scania with an average of 128 ng/L, which was comparable with *Stockholm Vatten 2010* where Henriksdal and Bromma

[11] Interkalibrerad läkemededelsanalys - ett samarbetsprojekt för ökad analyskvalite [Inter-calibrated pharmaceutical analysis - a collaborative project for greater analysis quality]. Kristianstad University 2017. Final report under preparation in autumn 2017.

treatment plants had concentrations of 196 ng/L (RSD = 44 %) and 140 ng/L (RSD = 56 %). Results from *National Screening 2011* indicated somewhat a higher occurrence with a range of 170-480 ng/L.

Fluconazole is an antifungal medication while *sertraline,* like citalopram above, is an antidepressant of the type SSRI. Both of these substances had a somewhat larger factorial difference of 35 and 12, respectively.

The concentrations of fluconazole varied between 3-105 ng/L; average 48 ng/L. Fluconazole was not analysed by *Stockholm Vatten 2010*, while *National Screening 2011* had significantly higher values between 72-1100 ng/L. The reason for this large different cannot be easily explained.

Sertraline occurred in concentrations between 4-47 ng/L and an average of 24 ng/L, which was comparable with *Stockholm Vatten 2011* where Henriksdal and Bromma treatment plants had concentrations of 26 ng/L (RSD = 59 %) and 21 ng/L (RSD = 72 %). In other words, this was a very large similarity. In *National Screening 2011,* there were concentrations between 0-32 ng/L.

None of these four pharmaceuticals showed any relationship between the treatment plants' size and the outlet concentrations.

7.1.7 Hormones

Hormones that were studied were the natural hormone estrone and the synthetic hormone levonorgestrel.

Estrone occurred in low concentrations in outlet wastewater, except at Ormanäs treatment plant, **Figure 10**. The levels are in line with *Stockholm Vatten 2010,* which did the analysis of estrone as a separate "special analysis" and estrone was found in the concentration 4.2 ng/L (RSD = 89 %) in the Henriksdal treatment plant and 0.5 ng/L (RSD = 46 %) in the Bromma treatment plant. Estrone was not included in the *National Screening 2011.*

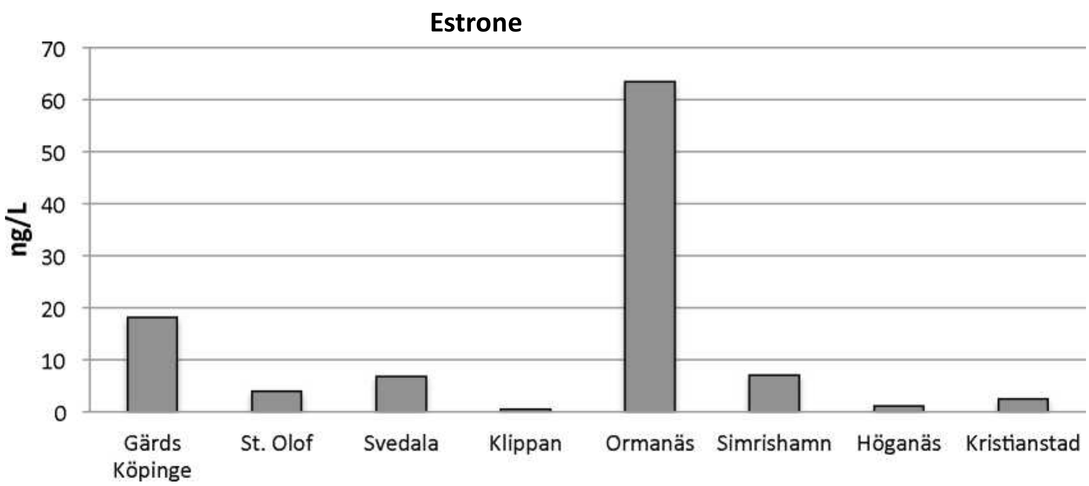


Figure 10. *Measured concentrations (ng/L) of the hormone estrone in the outlet water from the eight Scanian wastewater treatment plants. The treatment plants are listed in order of size as per Figure 1 above.*

Levonorgestrel was not found in detectable concentrations in any Scanian wastewater. Levonorgestrel was not analysed by *Stockholm Vatten 2010*, while *National Screening 2011* showed that the substance could not be found in any water.

7.1.8 Ketoconazole, zolpidem, methotrexate

These are three medications that occur in very low concentrations in all treatment plants.

Ketoconazole is an antifungal medication. The substance was measured in concentrations in the range 0-6 ng/L with an average of 3 ng/L. *Stockholm Vatten 2010* found 8 ng/L (RSD = 77 %) in Henriksdal treatment plant and 9 ng/L (RSD = 81 %) in Bromma treatment plant. *National Screening 2011* could only find ketoconazole in one out of 12 samples in total, but then with the remarkable concentration of 120 ng/L.

Zolpidem is used for sleeping difficulties and occurred in the range 1-4 ng/L with an average of 3 ng/L. *Stockholm Vatten 2010* indicated the substance in Henriksdal and Bromma treatment plants; 5.1 ng/L (RSD = 46 %) and 4.8 ng/L (RSD = 55 %), respectively. In *National Screening 2011,* zolidem was found in concentrations between 3-41 ng/L.

Methotrexate is given against rheumatic and inflammatory diseases, but is also a cytostatic used in cancer treatment. The substance could not be shown in any of the Scanian treatment plant samples in outlet water. Methotrexate was not analysed in either of the earlier Swedish studies *Stockholm Vatten 2010* or *National Screening 2011*.

7.2 Chemical emissions of pharmaceuticals from eight treatment plants in absolute mass

The treatment plants' basic parameters included an annual average of treated wastewater volume, **Table 1.** Using this information and the knowledge of outlet concentrations in **Table 2**, an estimate could be calculated of the annually emitted amount of pharmaceuticals in grams, **Table 4**. Then, each individual treatment plant's chemical emissions could be calculated in kilograms, as shown by **Figure 11**.

Table 4. *Outlet masses in grams of 21 pharmaceuticals from eight Scanian wastewater treatment plants.*
In this table, the treatment plants are listed in order of size while the pharmaceuticals are listed in alphabetical order.

	Gärds Köpinge	**Sankt Olof**	**Svedala**	**Klippan**	**Ormanäs**	**Simrishamn**	**Höganäs**	**Kristianstad**	**Total (g/year)**
Ciprofloxacin	0	0	0	0	0	0	0	0	0
Citalopram	9	21	239	185	227	247	286	659	1873
Clarithromycin	0	1	235	139	113	64	172	196	920
Diclofenac	44	114	1228	966	613	1541	1827	6107	12440
Erythromycin	0	1	704	227	17	254	162	1761	3127
Estrone	1	1	7	1	88	16	4	20	138
Fluconazole	0	3	59	71	98	55	182	860	1328
Ibuprofen	0	25	117	125	1608	1380	0	0	3255
Carbamazepine	11	120	769	600	735	525	1361	3844	7964
Ketoconazole	0	1	7	9	6	4	6	0	33
Levonorgestrel	0	0	0	0	0	0	0	0	0
Losartan	30	99	1013	374	116	1513	1058	1772	5975
Metoprolol	53	189	1573	1338	1171	2286	2935	5847	15392
Methotrexate	0	0	0	0	0	0	0	0	0
Naproxen	11	286	334	397	370	852	1162	976	4389
Oxazepam	7	94	407	548	484	737	993	3888	7159
Sertraline	1	5	36	54	66	19	55	31	267
Sulfamethoxazole	0	0	309	162	240	115	732	1704	3261
Tramadol	15	19	167	256	163	183	444	1704	2950
Trimethoprim	0	0	118	106	89	74	293	241	921
Zolpidem	0	0	5	3	1	3	9	29	50
Total (g)	184	980	7328	5558	6206	9868	11681	29638	71442
Total (kg)	**0.2**	**1.0**	**7.3**	**5.6**	**6.2**	**9.9**	**11.7**	**29.6**	**71.4**

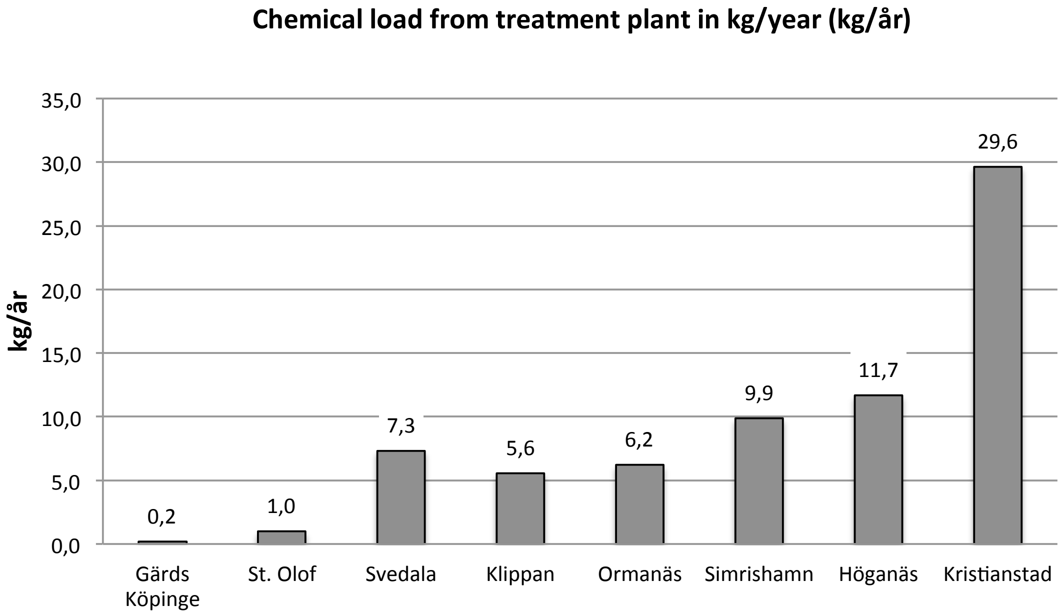


Figure 11. *Chemical emissions from eight Scanian wastewater treatment plants as the sum of 21 pharmaceuticals in kg/year (kg/år). The treatment plants are listed in order of size as per Figure 1 above.*

Of the 21 measured pharmaceuticals, the total emissions to the 8 different Scanian recipients amounts to 71,442 g ≈ 71 kg. In absolute figures, the smallest treatment plant in Gärds Köpinge releases the smallest amount of pharmaceuticals (approx. 0.2 kg) while the Kristianstads Treatment Plant releases the largest amount of pharmaceuticals (approx. 30 kg). By setting aside the amount of released pharmaceuticals per year against the volume of treated water in thousands of cubic metres, the relationship between the treatment plants' size and the amount of emissions of pharmaceuticals becomes clear, **Figure 12**.

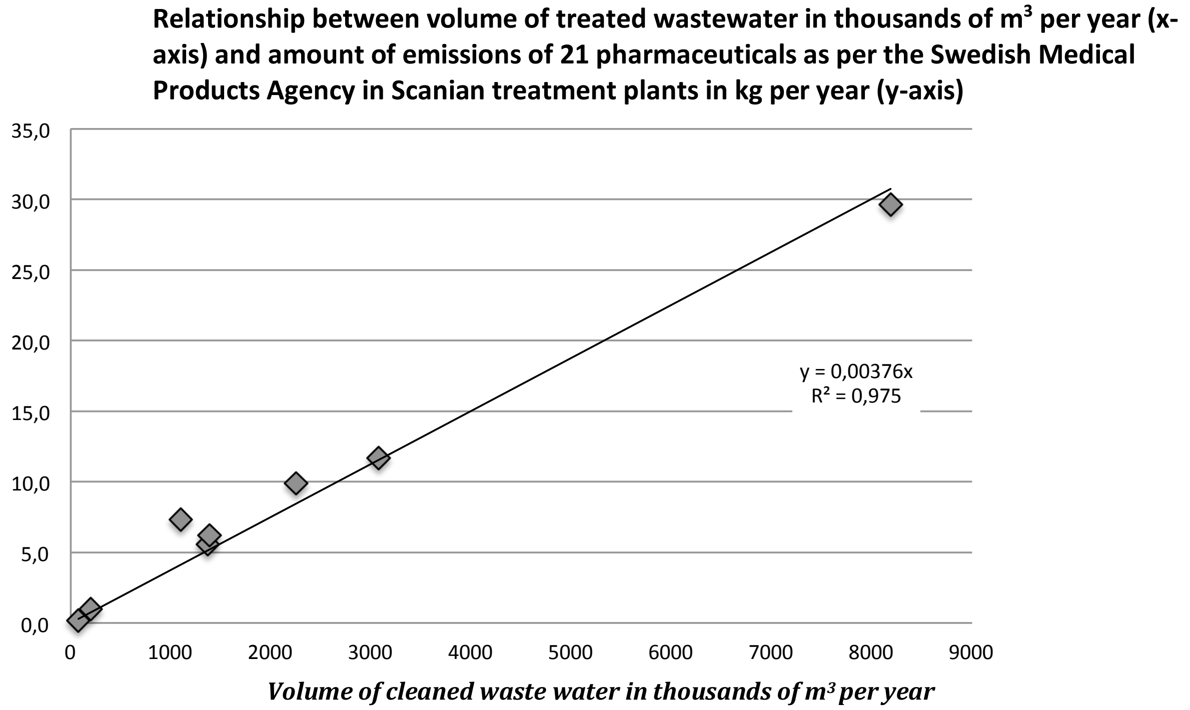


Figure 12. *The relationship between the amount of emitted pharmaceuticals from eight Scanian treatment plants as the sum of 21 pharmaceuticals in kg/year (y-axis) and the volume of treated wastewater. The treatment plants are listed in order of size as per Figure 1 above.*

From Figure 12, it is apparent that when a treatment plant releases 1 million cubic meter (1,000,000 m^3) of treated wastewater, at the same time 3.76 kg ~ 4 kg of the 21 pharmaceuticals the Swedish Medical Products Agency has on its watchlist passes through into the reciepient.

One should then note that these 21 substances are only a selective subset of several hundred substances that are used as medication today. The actual amount of medications that are released is thereby probably many times larger.

7.3 Treatment plants' ability to reduce pharmaceuticals (Reduction capacity %)

In addition to outlet concentrations, the inlet concentrations were measured to get a measurement of the reduction capacity of the different treatment plants. Inlet concentrations are found in **Appendix 2.** The reduction capacity expressed as a percentage of pharmaceuticals removed in the treatment plant is calculated is follows:

- Reduction capacity = ((Inlet conc. — Outlet conc.) / Outlet conc.) * 100 %

Table 5 presents the reduction capacity of the various substances at the different treatment plants. Sankt Olof is not included in the study as no samples were taken of inlet water. Pharmaceuticals reduced >80 % are marked in green. Pharmaceuticals reduced between 50-80 % are marked in yellow, and lastly, pharmaceuticals with a <50 % reduction are marked in orange.

Table 5. Percentage reduction of studied pharmaceuticals in seven Scanian wastewater treatment plants. Green indicates >80 % reduction, yellow 50-80 % reduction and orange <50 % reduction. In this table, the treatment plants are listed in order of size while the pharmaceuticals are listed in alphabetical order.

	Gärds Köpinge	Svedala	Klippan	Ormanäs	Simrishamn	Höganäs	Kristianstad	Average reduction (%)
Citalopram	23	36	-8	34	41	61	87	39
Ciprofloxacin	100	100	100	100	100	100	100	100
Clarithromycin	-9	27	-9	52	40	47	79	32
Diclofenac	25	-5	-45	10	-5	28	7	2
Estrone	-207	54	-75	16	48	-124	-	-48
Fluconazole	-155	-86	-114	-62	-61	-62	-54	-85
Ibuprofen	100	100	100	97	94	100	100	99
Carbamazepine	-146	-10	13	-10	80	-9	11	-10
Ketoconazole	90	95	83	91	97	98	100	94
Losartan	37	-2	-2	0	-23	46	59	17
Metoprolol	7	0	-4	-7	-11	57	36	11
Methotrexate	100	100	100	100	100	100	100	100
Naproxen	95	88	89	86	64	82	97	86
Oxazepam	-8	-11	-27	-16	-19	21	-14	-11
Sertraline	71	81	26	54	85	81	98	71
Sulfamethoxazole	99	55	16	25	64	48	67	53
Tramadol	6	2	9	11	-3	21	22	9
Trimethoprim	51	6	-157	-10	-20	9	69	-7
Zolpidem	-16	35	-38	44	36	47	44	22

As shown in **Table 5**, the reduction of the vast majority of the substances is weak with a reduction of <50% (orange). Some substances also show a negative reduction, which can partly be explained by a portion of the substance arriving at the treatment plant bound to particles, but being released to the water phase during the treatment process. Another explanation is that the inlet concentration to the treatment plant is underestimated somewhat due to the complicated matrix that inlet wastewater constitutes. Some differences between the treatment plants can be seen, where Kristianstad and Höganäs possibly have somewhat better capacity for treatment, but more extensive studies need to be done to establish this. In general, the picture is relatively similar in terms of treatment capacity.

To get a comprehensible picture of how effective Scanian treatment plants are at reducing individual pharmaceuticals, an average was taken of the seven treatment plants' reduction capacity for each substance. The results are presented in **Figure 13.** Estrone and fluconazole have been left out of this figure for the sake of clarity. In *National Screening 2011,* studies were also done of reduction capacity in four different treatment plants. Major variations were observed both between different pharmaceuticals and between different treatment plants. But to get a picture of how effective the treatment plants were in general regarding different types of pharmaceuticals, in *National Screening 2011* a mean of all four treatment plants (Skövde, Stockholm, Uppsala and Umeå) was calculated. This is also presented in **Figure 13.** Lastly, the reduction capacity of the Scanian treatment plants is also compared with that reported for Henriksdal treatment plant and Bromma treatment plant in *Stockholm Vatten 2010.*

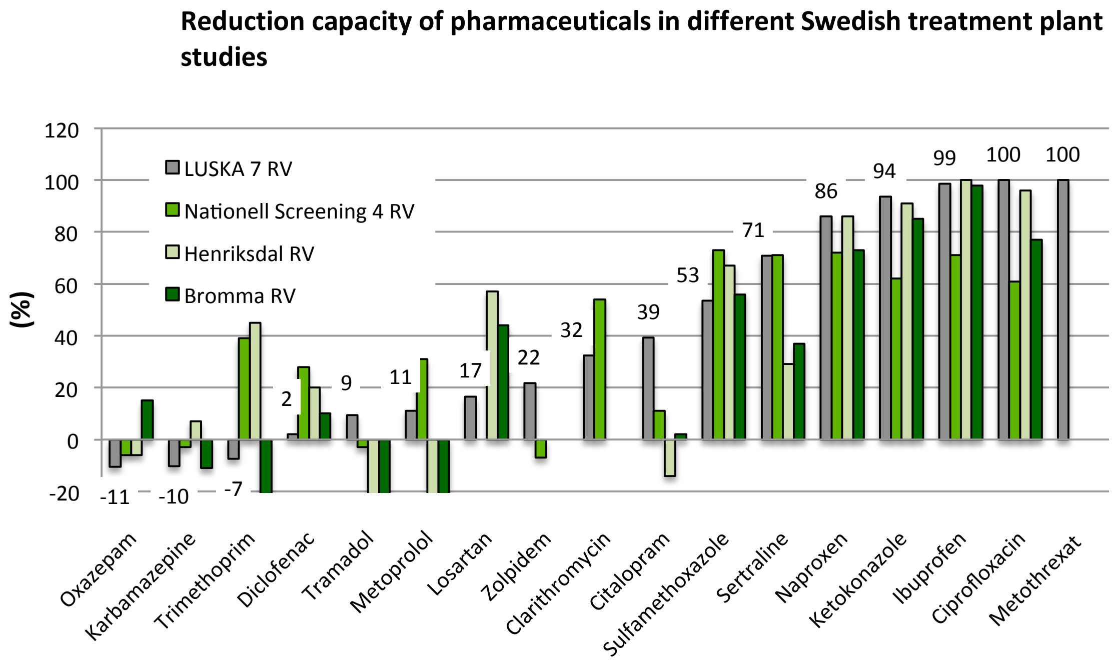


Figure 13. *Average reduction in per cent of the studied pharmaceuticals in seven Scanian treatment plants (7 RV = 7 WWTPs) compared with two earlier Swedish studies: National Screening 2011(4 RV = 4 WWTPs) Stockholm Vatten 2010 including Henriksdal and Bromma RV (WWTP). For details, see text.*

Figure 13 shows that only five substances are reduced >80%; methotrexate (100%), ciprofloxacin (100%), ibuprofen (99%), ketoconazole (94%) and naproxen (86%). This also agrees well with results from *National Screening 2011* and *Stockholm Vatten 2010*.

A good reduction of certain pharmaceuticals in the treatment plants can be due to various things besides decomposition. This is not discussed further here, but for two of the substances a contributing factor is binding to the sludge phase. In our own analyses of sludge, we were able to confirm that ciprofloxacin like ketoconazole were found in in very high concentrations in the sludge. Ibuprofen could not be detected in the sludge, while naproxen was found in relatively low concentrations. It is thereby processes other than adsorption to a solid phase that causes the reduction of ibuprofen and naproxen.

Two substances end up in the interval 50-80%: sulfamethoxazole (53 %) and sertraline (71 %). This is also somewhat in agreement with both of the previous Swedish studies even if reduction of sertraline is between 30-40% for Henriksdal and Bromma treatment plants. Other substances in the LUSKA study are reduced by <50% of the concentration in inlet water to the treatment plants. In general, this can be seen to also be the cases in *National Screening 2011* and *Stockholm Vatten 2010* even if substance-specific variations were tangible. For the vast majority of pharmaceuticals, there is generally an uncertainty about the more exact *percentage* effectiveness of various treatment plants' capacity to reduce the substances over time and space. But regardless of this uncertainty, it is clear that the treatment plants ability to remove the pharmaceuticals is very limited. In this respect, Scanian treatment plants do not deviate from earlier national studies. A deeper understanding of the treatment plants' existing technical design and its impact on the treatment capacity is subject to future studies, but requires more extensive analyses over time and space in close cooperation with the wastewater treatment organisations and their staff. One final observation is that when the results in **Figure 13** are compared with the results in **Figure 2**, it is clear that several of the substances that occur in the highest concentrations in the treated outlet wastewater are also poorly reduced in the treatment plants.

7.4 Occurrence of pharmaceuticals in Scanian lakes and streams

A crucial issue is if the recipients' concentrations of pharmaceuticals is affected by the discharge from the treatment plants. To investigate this, samples were taken upstream and downstream of the various treatment plants in the respective recipient. The possibility of taking samples upstream and downstream was dependent on the various treatment plants' placement in purely geographic terms. The results from the analyses of the samples are presented in **Table 6**.

7.4.1 Gärds Köpinge treatment plant and Vramsån River

Gärds Köpinge treatment plant discharges its treated wastewater into the Vramsån river equivalent to 8.75 m^3/h or 0.0024 m^3/s. The flow in Vramsån varies over the year, but the average annual flow in previous studies was stated at approximately 4 m^3/s[12], just before it goes over to become a part of the Helge Å River and its flow. The sampling facilities in Vramsån are shown by **Figure 14**.

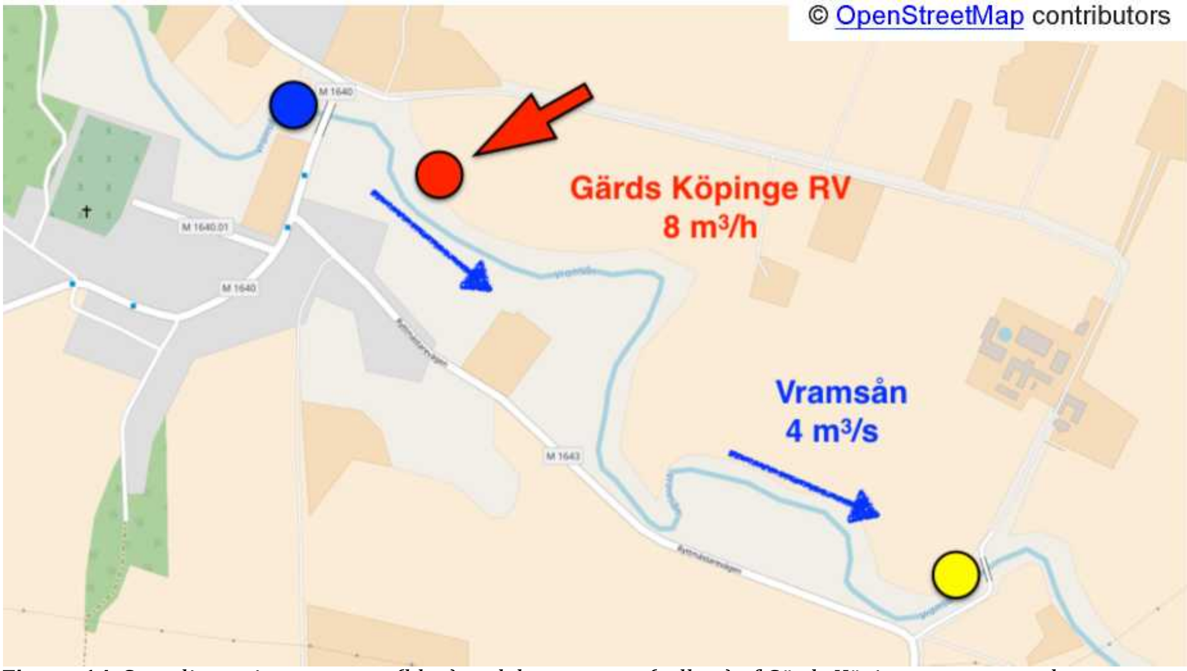


Figure 14. *Sampling point upstream (blue) and downstream (yellow) of Gärds Köpinge treatment plant. Approximate daily flow for the treatment plant and average annual flow for Vramsån River are shown in the figure.*

12 HELGE Å RIVER 2011 - With long-term diagram 1973-2011. Committee for Coordinated Control of the Helge River. 25/05/2012. 224 pages.

Table 6. *Measured concentrations in ng/L of 21 pharmaceuticals upstream (Up) and downstream (Down) of Scanian wastewater treatment plants. This table first lists the rivers and then the lakes. For Kristianstad treatment plant, the upstream sample point was located in the Helge River, which then runs through Hammarsjön where the downstream sample point was located. Västra Ringsjön did not have a clear upstream sample point and is placed last in the table.*

	Gärds Köpinge	**Gärds Köpinge**	**Klippan**	**Klippan**	**Sankt Olof**	**Sankt Olof**	**Svedala**	**Svedala**	**Kristianstad**	**Kristianstad**	**Ormanäs**
	Vramsån River Up	Vramsån River Down	Bäljane Å River Up	Bäljane Å River Down	Rörums Södra Å River Up	Rörums Södra Å River Down	Sege Å River Up	Sege Å River Down	Helge Å River Up	Hammarsjön Lake Down	V. Ringsjön Lake Down
Ciprofloxacin	0	0	0	0	0	0	0	0	0	0	0
Citalopram	0.5	0.8	0	2.8	0	2.0	0	6.2	0.3	5.1	0
Clarithromycin	0	0	0	2.0	0	0.1	0	7.1	0.2	2.7	0.25
Diclofenac	4.3	5.0	2.3	40.5	0.4	25.3	0.3	56.8	3.6	59.3	1.5
Erythromycin	0.6	0.8	1.4	8.8	0	0	0	33.0	0.8	23.5	0.5
Estrone	0.3	0.4	0.2	0.2	0.2	0.3	0.2	0.4	0.0	0.2	0.6
Fluconazole	0.3	0.2	0.6	2.0	0.0	0.4	0.1	1.4	0.6	6.1	1.2
Ibuprofen	0	0	0	0	0	0	0	0	0	0	0
Carbamazepine	1.5	1.8	6.7	27.0	0.1	24.8	0.3	37.9	5.9	59.3	12.4
Ketoconazole	0	0	0	0	0	0	0	0	0	0	0
Levonorgestrel	0	0	0	0	0	0	0	0	0	0	0
Losartan	1.2	1.7	1.9	11.9	0.0	19.1	0.0	32.6	2.2	15.7	1.7
Metoprolol	4.8	5.7	7.7	51.8	0.2	33.7	0.2	73.0	6.0	61.7	3.9
Methotrexate	0	0	0	0	0	0	0	0	0	0	0
Naproxen	3.8	6.1	4.0	13.2	0.0	56.8	3.2	11.8	7.4	7.2	3.1
Oxazepam	3.4	3.7	5.6	23.4	0.0	16.7	0.5	18.1	3.8	55.5	4.7
Sertraline	0	0	0	0.7	0	0	0	1.6	0	0.4	0
Sulfamethoxazole	0.5	0.3	4.0	10.9	0.0	0.0	0.0	11.1	1.9	34.1	3.4
Tramadol	1.4	1.7	1.4	11.2	0.0	4.3	0.1	8.8	1.2	26.2	1.2
Trimethoprim	0.3	0.2	0.6	3.3	1.7	1.3	0.2	5.4	0.9	2.3	0.6
Zolpidem	0	0	0	0	0	0	0	0.3	0	0.2	0

The results in **Table 6** for Gärds Köpinge show that this treatment plant has a relatively limited impact on the concentrations of pharmaceuticals in Vramsån River. Most of the substances are at the same level before and after the treatment plant. This is probably because the treatment plant's contribution to Vramsån's total flow is relatively low. A calculation of the relationship between the average annual flow (m^3/s) for Vramsån and the daily flow of wastewater (m^3/s) for Gärds Köpinge treatment plant yields a value of 1,667 (4/0.0024), which indicates extensive dilution. However, it is interesting to note that the background concentrations, upstream of Gärds Köpinge treatment plant, of known pharmaceuticals, such as diclofenac, metoprolol and oxazepam occur at a few ng/L. This is probably because a significantly larger treatment plant (Tollarp treatment plant) is located just a few kilometres upstream from Gärds Köpinge, which is probably the largest source of emissions in the Vramsån River. Studies are under way to determine Tollarp treatment plant's contribution to the chemical load in Vramsån River. This work is being done in the scope of an on-going EU project in the southern Baltic Sea called MORPHEUS 2017-2019. The project is being led by Erland Björklund and Ola Svahn (HKR), where sampling of wastewater and surface water is being done over two years in the four Baltic Sea countries Sweden, Germany, Poland and Lithuania. The results will be presented as they come available on the MORPHEUS website[13] and in reports and scientific articles.

The recipients' conservation value can also be crucial for whether or not steps need to be taken, but this is not addressed in detail in this report. However, for Vramsån, it can be mentioned that it is described as one of the "pearls of Vattenriket". On the Vattenriket website, it states: "*The good water quality has given many species good conditions. In Vramsån River, there is plenty of fish, both migratory and stationary salmon trout, as well as rare species, such as stone loach and gudgeon. All of the country's clams live in the river, including rarities such as fresh water pearl mussels and thick shelled river mussels. The clean oxygen-rich water is also home to a rich insect fauna and on the riverbed, researchers found up to 4,000 small animals of some 50 species in one single square metre.*"[14] The fresh water pearl mussel is of particular interest as it can reach more than 100 years of age and is protected in Swedish waters. HaV writes the following about this species on its website: "*Fresh water pearl mussels grow very slowly and have high standards on the environment they live in. A major problem is that they have difficulty breeding so steps are needed to ensure a viable stock of fresh water pearl mussels in Sweden.*"[15]. The fresh water pearl mussels are severely threatened today and are red listed. HaV also writes: *"Expansion of hydroelectric power, controls and pollutants have reduced the populations sharply in southern and central Sweden in the past 100 years. Individual stocks can survive many decades without functioning breeding, but gradually even very numerous stocks will vanish. The goal in the long term is for the fresh water pearl mussel to remain in viable populations throughout Sweden where the natural conditions allow it. To achieve this, greater consideration of the species is needed in land use and planning with the help of information and better knowledge, long-term protection for populations deemed to be of high conservation value, restoration of some water courses with pearl mussels and in water courses where measures are deemed to provide conditions for future recruitment and inventory and monitoring of known stocks.*" A reflection regarding Vramsån River is that even if the concentration of pharmaceuticals that the pearl mussel is subjected to are low, the chronic exposure becomes extensive for individuals that are subjected to chemicals in the water over a hundred years. To then only look at absolute concentrations can lead to an underestimation of the risks that exist for e.g. stationary species in a specific recipient like Vramsån.

7.4.2 Klippan treatment plant and Bäljane Å River

Klippan treatment plant discharges its treated wastewater into the Bäljane Å River at 156 m^3/h or 0.043 m^3/s. The flow in Bäljane Å River varies over the year, but the average annual flow has been stated in earlier studies as 2.4 m^3/s[16]. This earlier study also writes the following about the flows of Bäljane River in relation to the treatment plant's outflow and dilution. "*At normal flow quantity in*

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13 http://www.morpheus-project.eu

14 http://www.vattenriket.kristianstad.se/plats/vramsan.php

15 https://www.havochvatten.se/hav/fiske--fritid/arter/arter-och-naturtyper/flodparlmussla.html

16 Klippans läderfabrik [Klippan leather factory] - Supplemental studies of BÄLJANE RIVER 2005, Klippan Municipality. 60 pages.

Bäljane River (2.4 m³/s) and normal load from Klippan treatment plant (0.06 m³/s), the average dilution factor in Bäljane River is around 40-fold. At low flow periods (0.2 m³/s in Bäljane Å River), the load from Klippan treatment plant was assumed to be equivalent to around 0.03 m³/s. At low flow periods, the average dilution factor in the Bäljane Å River is therefore around 7-fold (0.2/0.03 = 6.67, our note). The dilution can probably be even lower on individual weeks/days. In extremely low flow periods, the dilution can probably drop down towards 2-fold." So, from this, it is apparent that the water in Bäljane River at certain points in time can be comprised of 1/3 treated wastewater, then a dilution factor of 2 would mean 2 parts river water/1 part wastewater = 2 fold dilution. The sampling facilities in Bäljane Å River are shown by **Figure 15**.

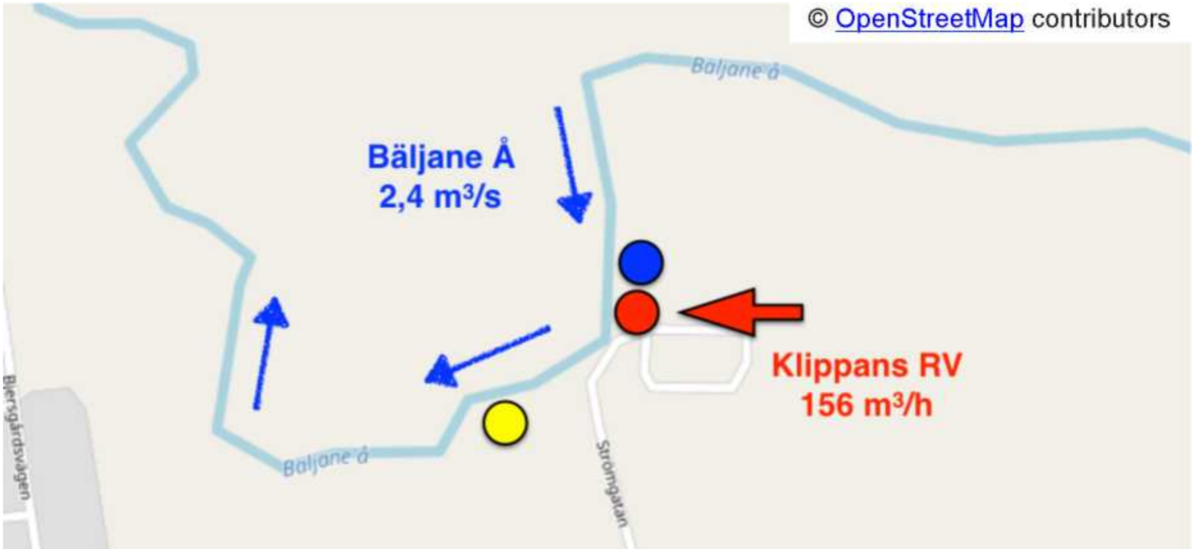


Figure 15. *Sampling points upstream (blue) and downstream (yellow) of Klippan treatment plant. Approximate daily flow for the treatment plant and average annual flow for Bäljane Å River are shown in the figure.*

Table 6 clearly shows that the concentrations downstream of the Klippan treatment plant is significantly higher than upstream, which is also apparent from **Figure 16**.

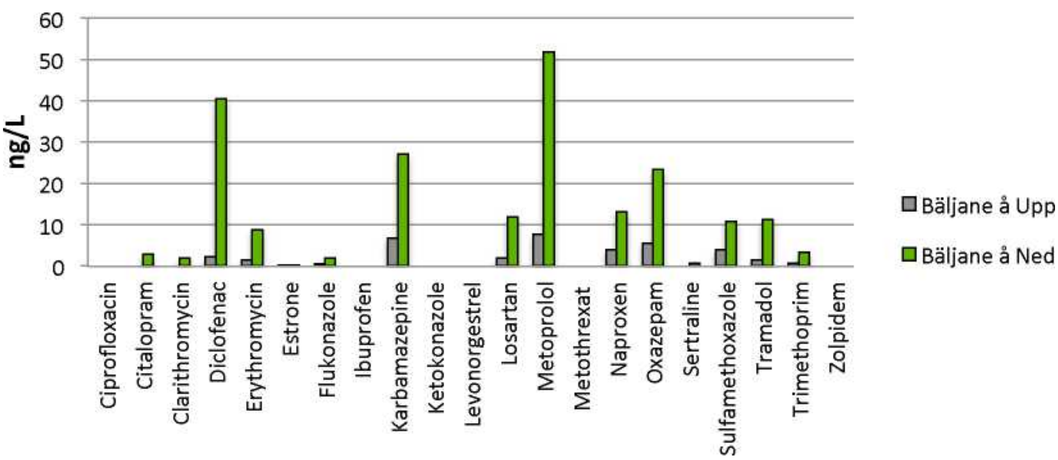


Figure 16. *Measured concentrations of pharmaceuticals in Bäljane Å River upstream (Upp) and downstream (Ned) of Klippan treatment plant.*

By dividing the concentrations downstream by those upstream for pharmaceuticals that occurred in measurable concentrations in both of the samples (diclofenac, erythromycin, fluconazole, carbamazepine, losartan, metoprolol, naproxen, oxazepam, sulfamethoxazole, tramadol and trimethoprim), one can see that the concentrations are around 6 times higher downstream of the Klippan treatment plant. Likewise, by dividing the outlet concentrations from Klippan treatment plant with the downstream concentrations, one can see that the outlet concentrations on average are 25 times higher. This agrees relatively well with the average dilution factor of 40 times as mentioned in the report above. A calculation of the relationship between the average annual flow (m^3/s) for Bäljane Å River and the daily low of wastewater (m^3/s) for Klippan treatment plant yields a value of 56, which is also on the same order of magnitude and indicates dilution, although not at all as strong as in Vramsån River above.

7.4.3 Sankt Olof treatment plant and Rörums Södra River

Sankt Olof treatment plant discharges its treated wastewater into Rörums Södra River. No value for flow is available, but a reasonable assessment is around 20 m^3/h or 0.0056 m^3/s. The flow in Rörums Södra River has been difficult to identify, but based on an assessment based on older studies, it should be around 0.4 m^3/s[17]. The sampling facilities in Rörums Södra River are shown by **Figure 17**.

Figure 17. *Sampling points upstream (blue) and downstream (yellow) of Sankt Olof treatment plant. Approximate daily flow for the treatment plant and average annual flow for Rörums Södra River are shown in the figure.*

The values in **Table 6** show elevated concentrations downstream from Sankt Olof treatment plant, which is further clarified in **Figure 18**.

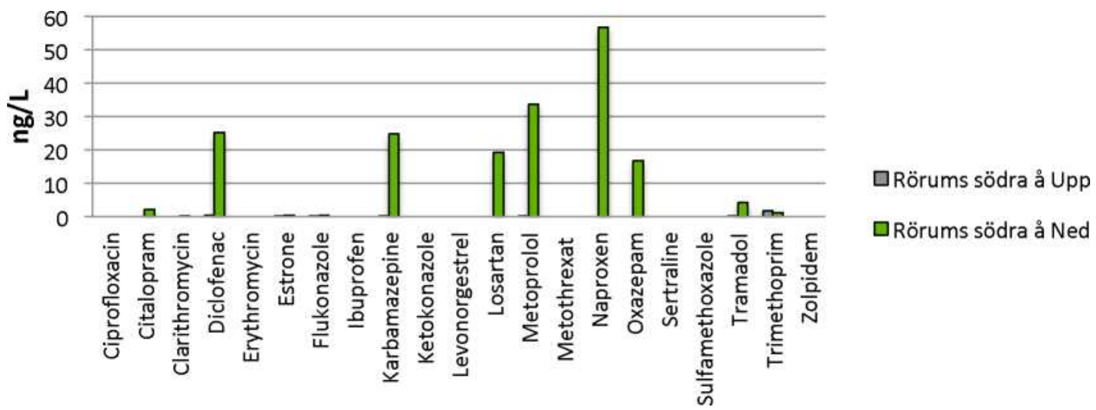


Figure 18. *Measured concentrations of pharmaceuticals in Rörums Södra Å River upstream and downstream of Sankt Olof treatment plant.*

17 Klammersbäck, Mölleån, Rörums norra å, Rörums södra å, Kvarnbybäcken. Österlen rivers - Input report. Environmental Control, County Administrative Board of Kristianstad, 1995. 111 pages.

A few things are worth noting in relation to the observations presented for Gärds Köpinge treatment plant in Vramsån River and Klippan treatment plant in Bäljane Å River above. Gärds Köpinge treatment plants is on the same order of magnitude as Sankt Olof treatment plant, nonetheless no higher concentrations of pharmaceuticals could be seen in Vramsån River due to more dilution. The calculation of the relationship between the average annual flow (m^3/s) for the rivers and the daily flow of wastewater (m^3/s) for the treatment plants in Gärds Köpinge and Sankt Olof yielded the values 1667 and 71, respectively. The dilution in Vramsån is accordingly 20 times higher than in Rörums Södra River, which is also reflected in significantly lower concentrations in Vramsån River.

A comparison with Klippan treatment plant shows that the relationship between the daily low of wastewater (m^3/s) and the average annual flow (m^3/s) for Bäljane Å River was 56. This is very close to the relationship that exists in Rörums Södra Å River where the corresponding value was 71. It is therefore not completely surprising that the measured concentrations in both of these rivers are similar. Based on upstream data in Rörums Södra Å River, Sankt Olof appears to be the largest source of pharmaceuticals.

7.4.4 Svedala treatment plant and Sege Å River

Svedala treatment plant discharges its treated wastewater into the Sege Å River equivalent to 125 m^3/h or 0.035 m^3/s. The average flow in Sege River has been given to be 2.7 m^3/s[18]. The sampling facilities in Sege Å River are shown in **Figure 19**.

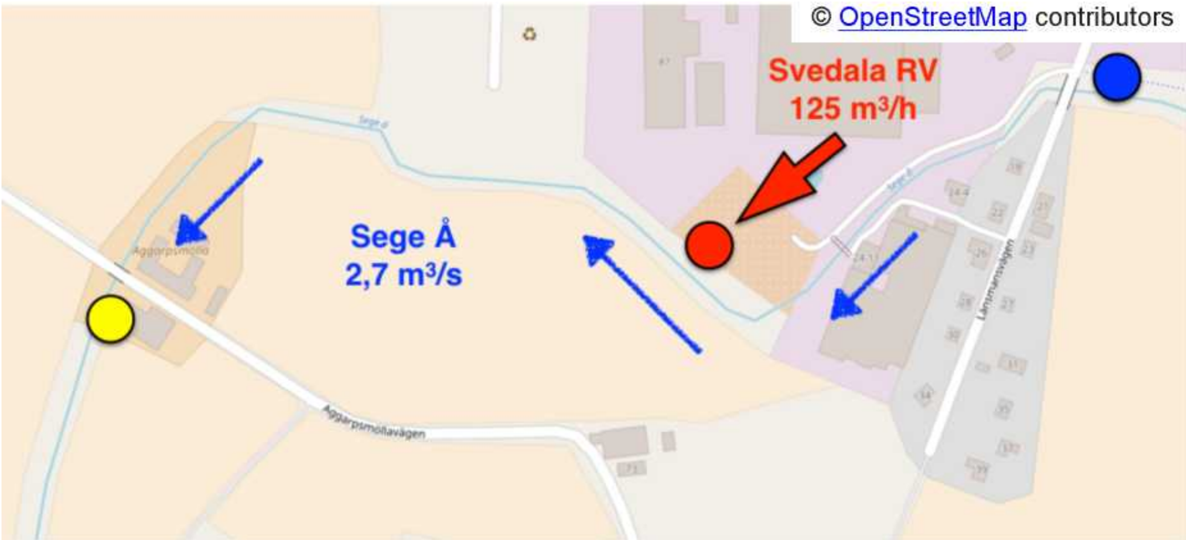


Figure 19. *Sampling points upstream (blue) and downstream (yellow) of Svedala treatment plant. Approximate daily flow for the treatment plant and average annual flow for Sege River are shown in the figure.*

The concentrations in **Table 6** show that the concentrations downstream of Svedala treatment plant are higher than upstream, which is clearly shown in **Figure 20**.

18 http://www.segea.se/Om-Segea.html

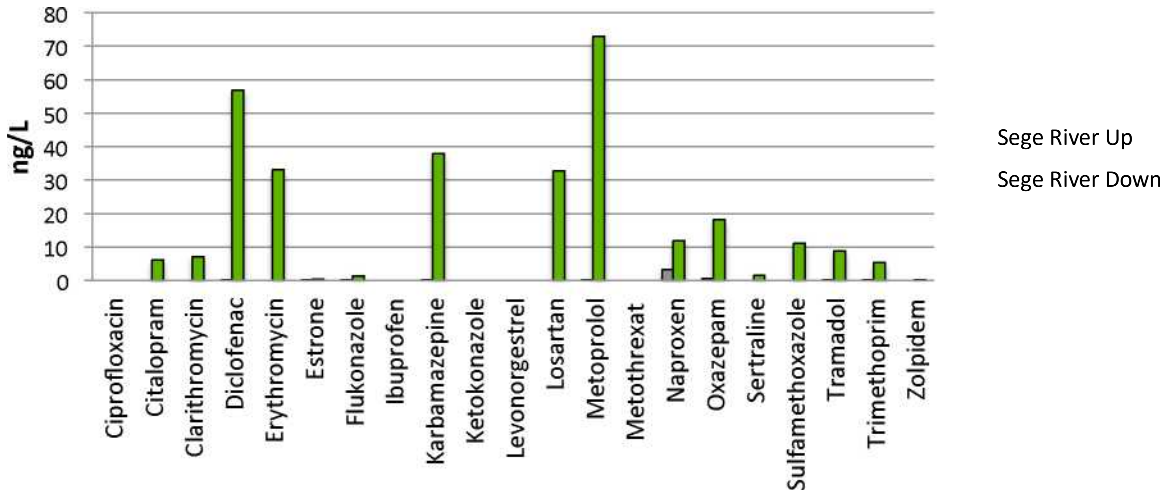


Figure 20. *Measured concentrations of pharmaceuticals in Sege Å River upstream and downstream of Svedala treatment plant.*

A calculation of the relationship between the average annual flow (m^3/s) for Sege River and the daily flow of wastewater (m^3/s) for Svedala treatment plant yields a value of 77. This value is very similar to both Bäljane Å River at 56 and Rörums Södra Å River at 71 as per above. Likewise, the measured concentrations downstream of Svedala treatment plant in Sege Å River are very close to those reported in both Bäljane Å and Rörums Södra Å Rivers.

The dilution factor in the four studied Scanian rivers seems to be absolutely central for the concentrations found downstream of the treatment plants.

7.4.5 Kristianstad treatment plant and Hammarsjön Lake

Kristianstad treatment plant discharges its treated wastewater into the Hammarsjön Lake equivalent to 958 m^3/h or 0.27 m^3/s. The upstream sampling point was in Helge Å River, which at this point has an approximate flow of 39 m^3/s according to the same report as for Gärds Köpinge above (see footnote 12). Helge River feeds into the north-western part of Hammarsjön Lake while the sampling point downstream of Kristianstad Treatment Plant is located in an inlet called "Ekenabben" in the north-eastern part of Hammarsjön Lake, which has an estimated volume of 782,000 m^3. The sampling facilities are shown by **Figure 21**.

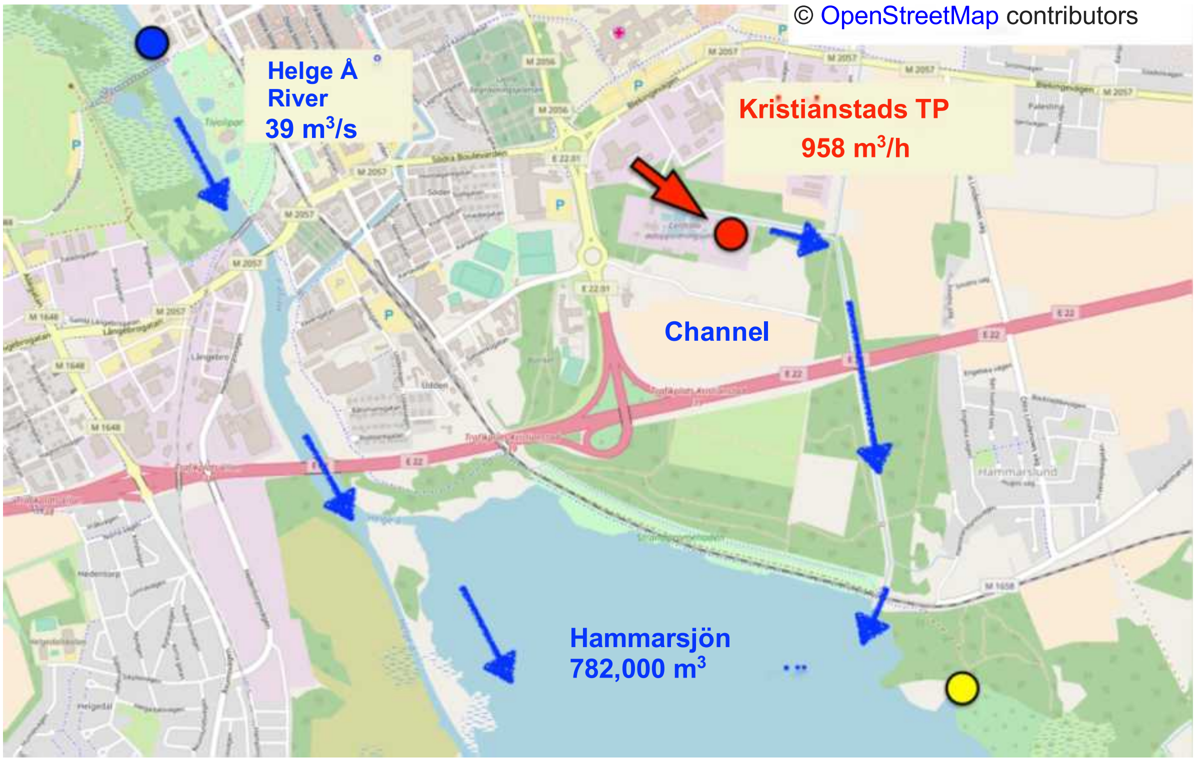


Figure 21. *Sampling points upstream (blue) and downstream (yellow) of Kristianstad treatment plant. Approximate daily flow for the treatment plant and the average annual flow for Helge Å River, and approximate water volume of Hammarsjön Lake are shown in the figure.*

The concentrations reported in **Table 6** show a clear occurrence of pharmaceuticals in the inlet "Ekenabben" that is located around 2 km downstream from Kristianstad treatment plant in Hammarsjön Lake compared with the upstream sample point in Helge River, which is shown in **Figure 22**.

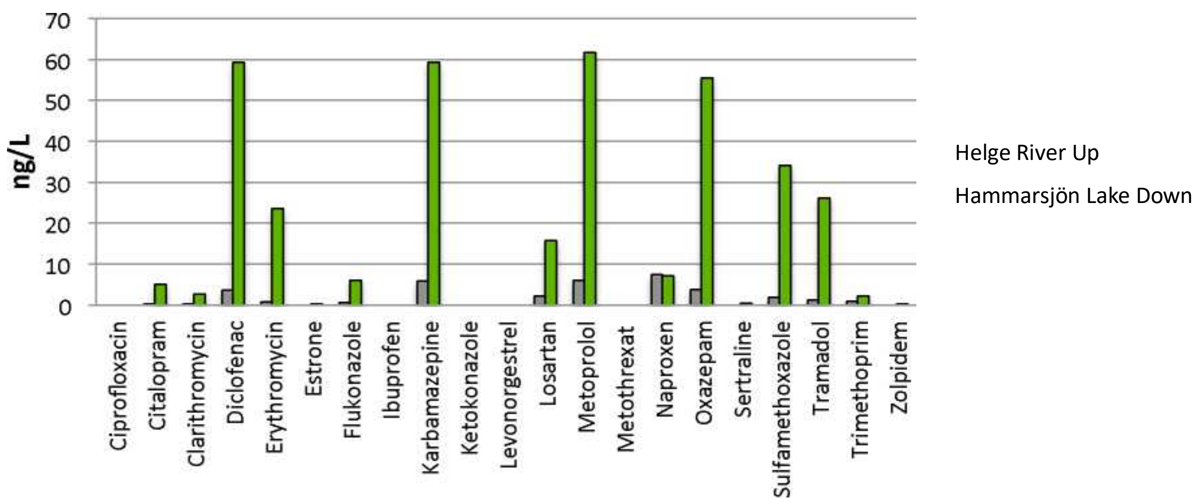


Figure 22. *Measured concentrations of pharmaceuticals in Helge Å River upstream and Hammarsjön Lake downstream of Kristianstad treatment plant.*

A comparison shows that the concentrations in Hammarsjön on average are 13 times higher than the concentrations show in Helge Å River upstream of the treatment plant. Likewise, the outlet concentrations from Kristianstad treatment plant and the downstream concentrations in Hammarsjön Lake show that the outlet concentrations from the treatment plant on average are 12 times higher. So Hammarsjön Lake dilutes the concentration of pharmaceuticals 12 times before they reach the inlet "Ekenabben". At the same time, a simple calculation shows that since Hammarsjön Lake has a total volume of around 782,000 m^3 and the treatment plant discharges

958 m^3/h, the treatment plant's water is a relatively large contribution to Hammarsjön Lake's total water volume. Through the following calculation 782,000 (m^3)/958 (m^3/h) = 816h = 34 days ~ 1 month, one sees that in one month, a volume equivalent to Hammarsjön's entire water volume has been added in the form of treated wastewater. The fact that the concentrations are nonetheless not higher than they are is probably because Helge Å River at a rate of 39 m^3/s = 140,400 m^3/h flows through Hammarsjön. So, Helge River shifts out the water in Hammarsjön Lake in nearly 6 h. The flow profile in Hammarsjön has not been identified, but despite the lake's size and large through-flow of water, relatively high concentrations can nonetheless be measured at the "Ekenabben" inlet.

7.4.6 Ormanäs treatment plant and Västra Ringsjön Lake

Ormanäs treatment plant discharges its treated wastewater into the Västra Ringsjön Lake with a flow of 184 m^3/h or 0.051 m^3/s. No upstream point was located. Ormanäs discharges its water out into the Västra Ringsjön Lake. The exact position was not known at the time of sampling, but probably a ways out into the lake. Instead, a sample was taken from the water's edge 2 metres out from the beach in a south-westerly direction from the treatment plant as shown in **Figure 23.** Västra Ringsjön Lake has an estimated volume of 39,110,000 m^3.

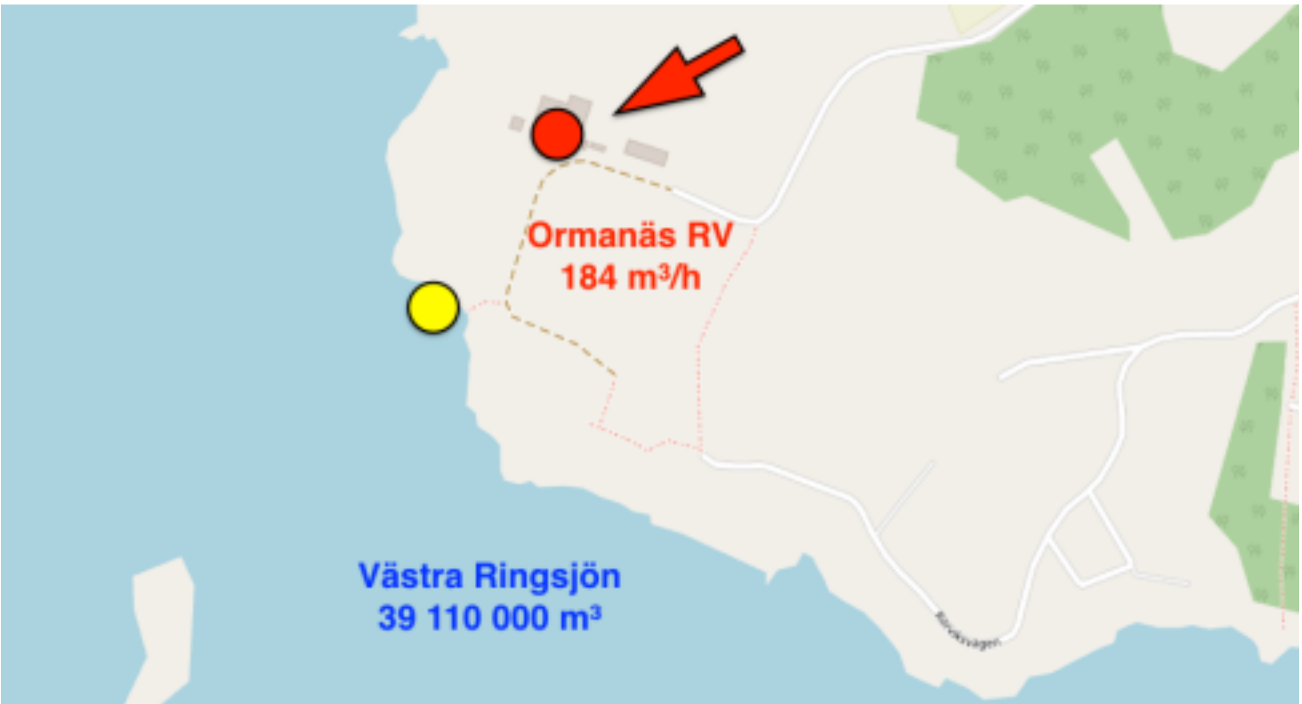


Figure 23. *Sampling point downstream (yellow) Ormanäs treatment plant. Approximate daily flow for the treatment plant and approximate water volume in the Västra Ringsjön Lake are shown in the figure.*

A comparison of the concentrations of pharmaceuticals measured in both of the Scanian lakes is shown in **Figure 24**.

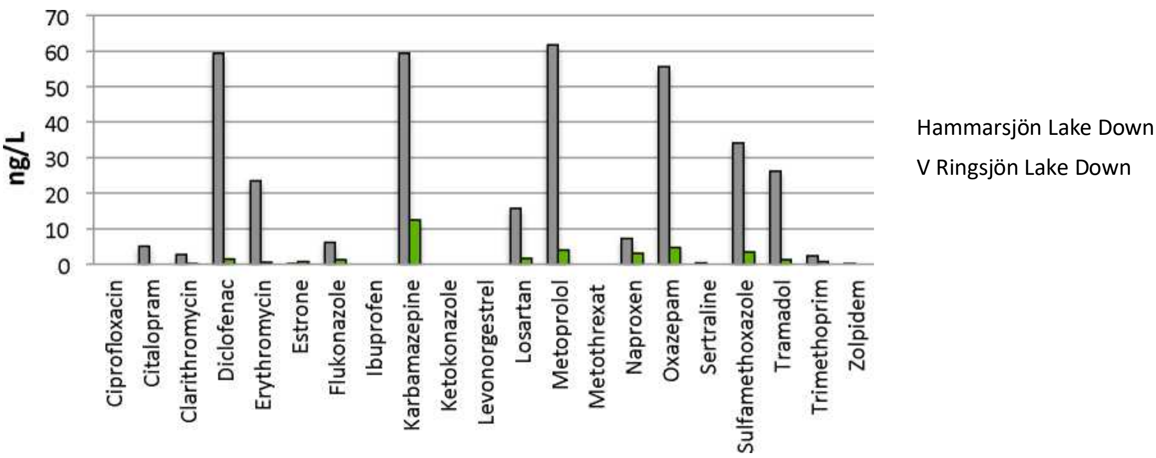
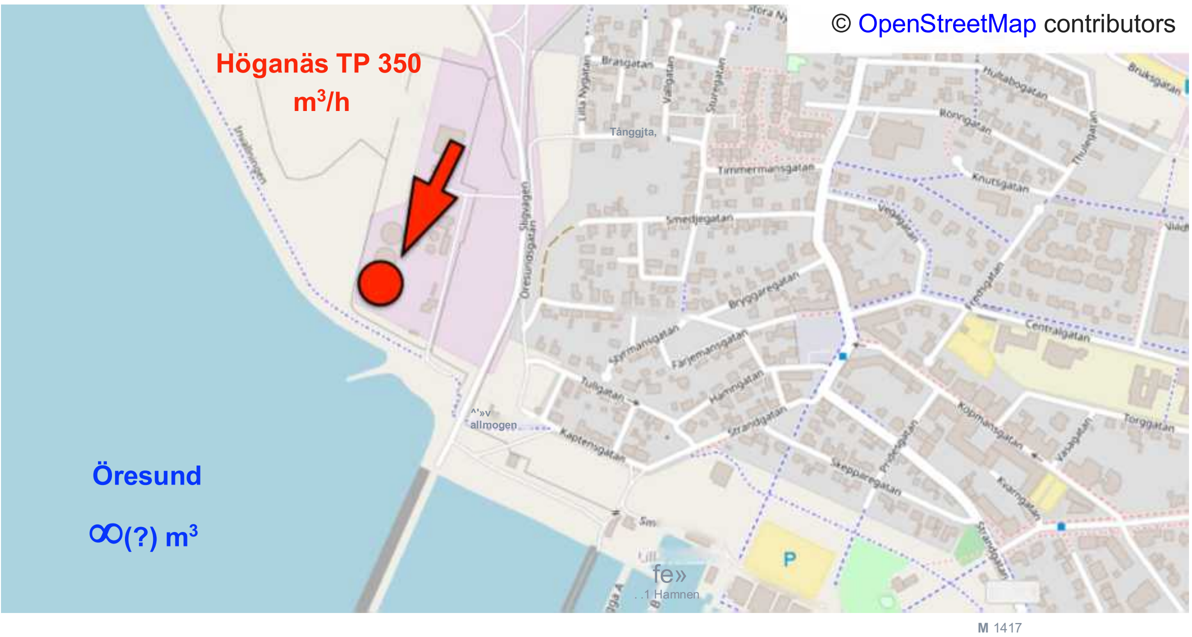


Figure 24. *Comparison of measured concentrations of pharmaceuticals in Västra Ringsjön Lake and Hammarsjön Lake downstream from Ormanäs treatment plant and Kristianstad treatment plant, respectively.*

On average, the concentrations in Hammarsjön were 14 times higher than in Västra Ringsjön. As previously mentioned, we do not know exactly where the discharge in Västra Ringsjön takes place or what the currents in the lake look like, at the same time, we know that the volume of Västra Ringsjön is a factor of 50 times larger than Hammarsjön and the dilution is thereby greater. One can also see that Ormanäs treatment plant only constitutes a relatively limited contribution to Västra Ringsjön's total water volume. Through the following calculation 39,110,000 (m^3)/184 (m^3/h) = 212,554 h = 8,856 days = 24 years, one can see that only after a quarter of a century has a volume equivalent to the entire Västra Ringsjön's water volume been added in the form of treated wastewater. On the other hand, Västra Ringsjön does not have the through-flow of a river as large as Helge Å River and the water turnover in Västra Ringsjön is thereby probably more limited.

7.4.7 Höganäs treatment plant and Öresund and Simrishamn treatment plant and the Baltic Sea

Two of the treatment plants discharge into a sea environment, Höganäs treatment plant and Simrishamn treatment plant. For both of these treatment plants, no downstream samples were taken. The treatment plants' locations are shown by **Figure 25**.



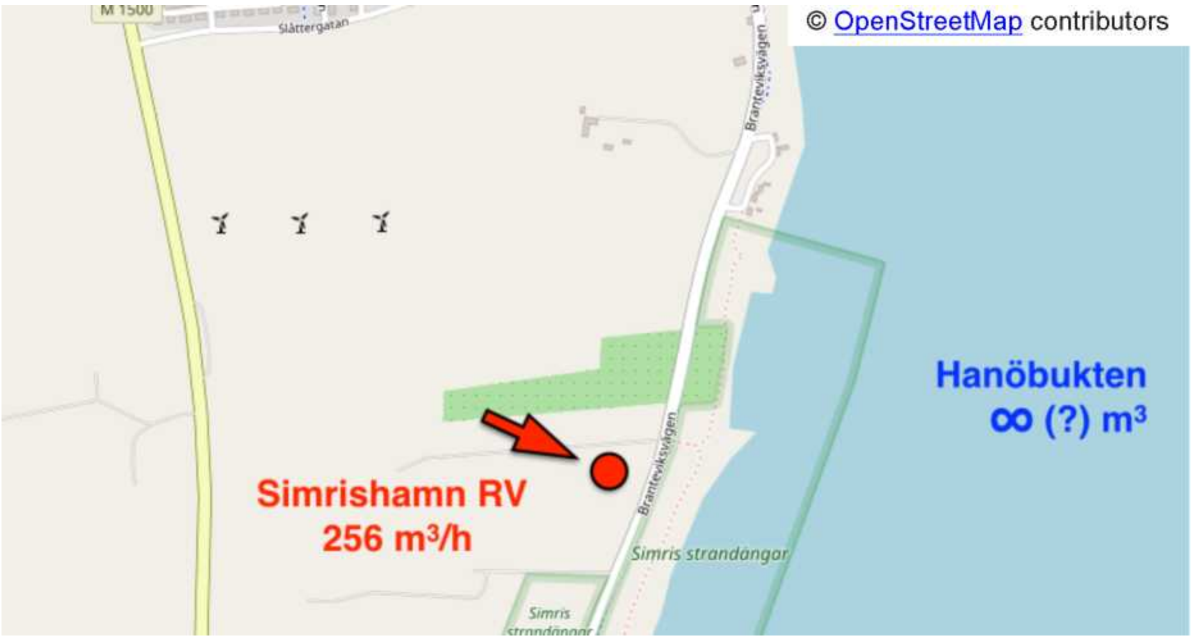


Figure 25. *Placement of the treatment plants in Höganäs and Simrishamn and recipients for treated wastewater. Approximate daily flow for the treatment plant is shown in the figure.*

For both of these treatment plants, the volume of the recipient is unknown. Öresund is possibly a less sensitive recipient than the Baltic Sea. At the same time, it is a significant number of kg of pharmaceuticals that are discharged into Öresund every year (see Section 8 below). The sampling of Hanöbukten Bay is currently under way in a different Region Skåne project with the aim of slowly mapping the picture of the "chemical cocktail" that HaV speaks of in its report (see footnote 1). From a more general perspective, one can also begin thinking about the wisdom of discharging fresh water into salt water where the former can be reclaimed in fresh form again only at great expense. A water shortage exists during the year in several parts of the country and a more circular thinking around the fresh water should be taken into account in such areas.

8. Pharmaceutical emissions in all of Scania based on data from LUSKA

Through a few simple calculations from data obtained in the LUSKA project, see mainly Section 7.2, one can make a rough estimate of the pharmaceutical emissions of the whole of Scania. Especially the western side of Scania has large cities with extensive discharges of treated wastewater, while the population size in southern and eastern Scania is somewhat lower, and limited to a few small and medium-sized cities.

8.1 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in North-western Scania.

North-western Scania has multiple municipalities, **Image 1.** In the estimate below of the amount of emitted pharmaceuticals, a delimitation has been made to the following nine municipalities: *Båstad*, *Ängelholm*, *Höganäs*, *Helsingborg*, *Åstorp*, *Klippan*, *Bjuv*, *Svalöv* and *Landskrona*. The organisation Nordvästra Skånes Vatten och Avlopp AB (NSVA) is active in this part of Scania and is an example of a water utility organisation with a broad spectrum of treatment plant types[19]. On NSVA's website, one can read that since 2009, they are responsible for the municipal water and wastewater operations in six of the selected municipalities above: *Bjuv*, *Båstad*, *Helsingborg*, *Landskrona*, *Svalöv* and *Åstorp*. There are 10 treatment plants in total in NSVA that distinguish themselves by size and treatment technology. It is apparent that the Öresundsverket treatment plant in Helsingborg is their largest wastewater treatment plant, which treats water from 130,000 people, and a number of large and small industries. This treatment plant thereby has certain similarities with the Kristianstad treatment plant. Röstånga treatment plan is NSVA's smallest treatment plant where water from around 800 people is treated, which in terms of size can be compared to Sankt Olof treatment plant. On NSVA's website, environmental reports are available for all 10 treatment plants for 2013. Here, the volume of treated wastewater is also stated as per **Table 7** below.

Table 7. *Estimate of annual amount of emissions of 21 pharmaceuticals in North-western Scania based on available environmental reporting for 2013 from Nordvästra Skånes Vatten och Avlopp AB (NSVA) an on the relationship between the volume of treated wastewater in thousands of m³/year and emissions of pharmaceuticals in kg/year as per Figure 12.*

Treatment plant	Volume m^3/day	Volume m^3/year	Volume thousands m^3/year	Amount pharmaceuticals kg/year
Torekov TP, Båstad	3,239	1,182,235	1,182	4.4
Öresundsverket, Helsingborg	65,491	23,904,215	23,904	89.9
Lundåkraverket, Landskrona	12,551	4,581,115	4,581	17.2
Kvidinge TP Åstorp	331	120,815	121	0.5
Nyvångsverket, Åstorp	3,657	1,334,805	1,335	5.0
Ekebro TP, Bjuv	3,046	1,111,790	1,112	4.2
Eketorp TP, Bjuv	1,357	495,305	495	1.9
Kågeröds TP, Svalöv	923	336,895	337	1.3
Röstånga TP, Svalöv	296	108,040	108	0.4
Svalövs TP, Svalöv	1,467	535,455	535	2.0
Total:	**92,358**	**33,710,670**	**33,711**	**126.8**

The total sum of emissions for these 10 treatment plants is accordingly 126.8 kg of pharmaceuticals every year where the majority of the pharmaceuticals are discharged into Öresund.

Added to this are *Höganäs* Municipality and its treatment plant that according to our own study releases 11.7 kg, and *Klippan* Municipality where we found that its treatment plant discharges 5.6 kg/year. Besides this, *Ängelholm* Municipality can be added, which according to their website treats

19 http://www.nsva.se/var-verksamhet/spillvatten/reningsverk/

32 http://www.mittskanevatten.se/var-verksamhet/spillvatten/

around 11,000 m^3 wastewater/day which corresponds to 4,015,000 m^3 wastewater/year or 4,015 thousand m^3/year[20]. This would be equivalent to emissions of 15.1 kg of pharmaceuticals.

Altogether, the emissions in North-western Scania's water are estimated at 126.8+11.7+5.6+15.1 = 159.2 ~ **160 kg**/year of these 21 pharmaceuticals.

8.2 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in South-western Scania

South-western Scania has multiple municipalities, **Image 1.** In the estimate of the amount of pharmaceuticals below, a delimitation has been done to the following municipalities: *Malmö*, *Vellinge*, *Burlöv*, *Lund*, *Svedala*, *Kävlinge*, and parts of *Lomma*. VA SYD AB is a regional organisation in South-western Scania with a broad spectrum of treatment plant types just like NSVA in the north-west. VA Syd treats wastewater for more than half a million people[21]. One of Sweden's largest treatment plants is in VA Syd and is called Sjölundaverket. Sjölundaverket handles most of *the City of Malmö*, *Burlöv* and parts of *Lomma*, *Staffanstorp* and *Svedala* municipalities. On VA Syd's website, there is a description that they accept a full 1,350 litres of wastewater every second (1,350 L/s). But *Klagshamn* treatment plant is large and treats wastewater from south-western part of the *City of Malmö* and all of *Vellinge Municipality*. This treatment plant accepts 220 litres of wastewater every second (220 L/s). But VA Syd also has several other treatment plants as shown in **Table 8** based on available Environmental Reports 2015.

Table 8. *Estimate of annual amount of emissions of 21 pharmaceuticals in South-western Scania based on available Environmental Reports 2015 from VA Syd and on the relationship between the volume of treated wastewater in thousands m^3/year and emissions of pharmaceuticals in kg/year as per Figure 12.*

Treatment plant	Volume m^3/day	Volume m^3/year	Volume thousands m^3/year	Amount pharmaceuticals kg/year
Sjölundaverket, City of Malmö, Burlöv, etc.	-	42,258,000	42,258	158.9
Klagshamn TP, City of Malmö, Vellinge	-	8,305,000	8,305	31.2
Källby TP, Lund	-	11,290,000	11,290	42.5
Södra Sandby TP, Lund	-	830,000	830	3.1
Veberöd TP, Lund	-	340,500	341	1.3
Revinge TP, Lund	-	106,158	106	0.4
Torna Hällestad TP, Lund	-	46,500	47	0.2
Håstads TP, Lund	-	98,373	98	0.4
Ellinge TP, Eslöv	-	4,433,000	4,433	16.7
Billinge TP, Eslöv	-	141,800	142	0.5
Stockamöllans TP, Eslöv	-	65,100	65	0.2
Stehag TP, Eslöv	-	299,756	300	1.1
Flyinge TP, Eslöv	-	206,000	206	0.8
Löberöd TP, Eslöv	-	152,200	152	0.6
Hurva TP, Eslöv	-	88430	88	0.3
Örtofta TP, Eslöv	-	33800	34	0.1
Total:		**68694617**	**68695**	**258.3**

The total sum of these 16 treatment plants is accordingly 258.3 kg of pharmaceuticals every year where the majority is discharged into Öresund.

The list above is not comprehensive; among other things, information is unavailable about Borgeby treatment plant in Lomma Municipality, which treats water from Bjärred, Fjelie, Flädie and smaller surrounding villages. Nor has Staffanstorp Municipality with a population of around 24,000 people have been included in the calculation, where Staffanstorp treatment plant treats

[20] https://www.engelholm.se/Bygga-bo-miljo/Vatten-och-avlopp/Avloppsreningsverk/Kommunalt-avlopp/

[21] http://www.vasyd.se/Artiklar/Avlopp/Avloppsvatten

98% of all wastewater in the municipality. However, *Kävlinge* Municipality and its treatment plant are available, which according to their Environmental Report 2016, treated a total of 6,758 m^3 wastewater/day, which corresponds to 2,466,670 m^3/year and a pharmaceutical emission of around 9.3 kg. In addition, there is Svedala Municipality whose treatment plant according to our own study discharges 7.3 kg.

Altogether, the emission in South-western Scania's water is estimated at 258.3+9.3+7.3 = 274.9 ~ **275 kg**/year of these 21 pharmaceuticals.

8.3 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in Southern Scania

As Southern Scania, we included three municipalities: *Trelleborg*, *Skurup* and *Ystad*. *Trelleborg* Municipality's website contains a short summary of their wastewater operations[22]. There, it is stated that the municipality has five wastewater treatment plants Trelleborg, Smygehamn, Västra Alstad, Sjörup and Grönalund, which in total treat 5,000,000 m^3 wastewater annually. This provides an approximate emission of pharmaceuticals of approx. 18.8 kg.

Ystads Municipality's website describes that Ystad's treatment plant treats wastewater from both *Ystad* and *Skurup* Municipality[23]. In an Environmental Report 2015 from Ystad treatment plant, it is stated that they treat 7,212,600 m^3 wastewater/year which corresponds to pharmaceutical emissions of approx. 27.1 kg.

The three southern Scanian coastal municipalities thereby contribute an annual emission of 18.8+27.1 = 45.9 ~ **46 kg**/year of these 21 pharmaceuticals alone. Discharges are made to the Baltic Sea.

8.4 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in South-eastern Scania

We have included three municipalities in South-eastern Scania: *Simrishamn, Tomelilla*, and *Sjöbo*.

Simrishamn Municipality has more than 19,000 residents. The largest treatment plant is Stengården treatment plant in Simrishamn, which was also included in this study. This treatment plant discharges around 9.9 kg of pharmaceuticals into the Baltic Sea. Besides Stengården treatment plant, Simrishamn Municipality operates another three smaller treatment plants in Kivik, Sankt Olof, Östra Vemmerlöv, and Ravlunda, according to the municipality's website[24]. No information on treated water volumes could be found, only what dimensioning the smaller treatment plants have. In order, these are 3,000 PE, 1,000 PE, 250 PE and 140 PE. Of these four, we have in this study sampled Sankt Olof treatment plant and measured its discharge to 1.0 kg.

Tomelilla Municipality has around 14,000 residents. To treat the wastewater, the municipality operates six treatment plants according to the municipality's website[25]. The largest of these is Tomelilla's central treatment plant (ARV Rosendal). However, we have not calculated a value for Tomelilla as the information about the municipality's volume of treated wastewater could not be identified.

Sjöbo Municipality has around 19,000 residents, and most of the wastewater is treated in Sjöbo Treatment Plant and the rest of the water is treated in seven smaller treatment plants, according to

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22 http://www.trelleborg.se/sv/bygga-bo-miljo/vatten-och-avlopp/avlopp/avloppsverk-i-trelleborg/

23 http://www.ystad.se/boende--miljo/vatten-och-avlopp/anlaggningar/avloppsverk/

24 http://www.simrishamn.se/sv/bygga_bo/Vatten--Avlopp/Avlopp/

25 https://www.tomelilla.se/bygga-bo-miljo/vatten-och-avlopp/avlopp/

the municipality's website[26].

However, we have not calculated a value for Sjöbo as the information about the municipality's volume of treated wastewater could not be identified.

In this report, the three south-east Scanian municipalities are represented by Simrishamn Municipality and our own measurements in Stengården treatment plant and Sankt Olof treatment plant that together have an annual discharge of 9.9 + 1.0 = 10.9 ~ **11 kg**/year of these 21 pharmaceuticals. Discharges are made to the Baltic Sea.
Based on the number of municipal residents in the three municipalities, it is however reasonable to assume that the total load in South-eastern Scania is around three times higher than that stated for Simrishamn Municipality.

8.5 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in North-eastern Scania

We have included three municipalities in North-eastern Scania: *Kristianstad*, *Bromölla*, *Östra Göinge* and *Bromölla* municipalities.

Kristianstad Municipality has around 84,000 residents. The largest treatment plant is Kristianstad central treatment plant, which was also included in this study. This treatment plant discharges around 29.6 kg of pharmaceuticals into Hammarsjön Lake. In addition to this large treatment plant, Kristianstad Municipality has another 11 other treatment plants, e.g. in Tollarp and Gärds Köpinge, where the latter was a part of this study and with a discharge of 0.2 kg. No information on treated water volumes was able to be found on the municipality's website[27]. But e.g. Tollarp has a population of more than 3,000 people and with extensive industry and thereby probably affects its discharge recipient Vramsån River with pharmaceuticals.

North of Kristianstad are the three municipalities *Bromölla*, *Östra Göinge* and *Bromölla*. All of these municipalities' water is treated by the company Skåne Blekinge Vattentjänst AB (SBVT)[28]. On their website there is information on the number of treatment plants in each municipality and the volume of treated water.

Bromölla Municipality has one treatment plant in the municipality today that treats around 1,270,500 m^3 of wastewater per year. This corresponds to a discharge of approx. 4.8 kg.

Östra Göinge municipality has several treatment plants today in Knislinge, Broby, Sibbhult, Immeln, Östanå, Boalt and Kräbbleboda. In total, the plants treat around 1,600,000 m^3 wastewater per year. This corresponds to a discharge of approx. 6.0 kg.

Osby Municipality has five treatment plants today in Osby town, Lönsboda, Killeberg, Hökön and Visseltofta. In total, these treatment plants also treat around 1,600,000 m^3 wastewater per year like Östra Göinge Municipality. This corresponds to a discharge of approx. 6.0 kg.

Altogether, the emission in North-eastern Scania's water is estimated at 29.6+0.2+4.8+6.0+6.0 = 46.6 kg ~ **47 kg**/year of these 21 pharmaceuticals.

26 http://www.sjobo.se/bygga-bo-och-miljo/vatten-och-avlopp/kommunalt-vatten-och-avlopp/spillvatten-och-rening/

27 https://www.kristianstad.se/sv/bygga-bo-och-miljo/vatten-och-avlopp/avlopp/kommunalt-avlopp/

28 https://www.sbvt.se/om-oss

8.6 Estimate of the amount of pharmaceutical emissions of 21 pharmaceuticals in Central Scania

We have included five municipalities in Central Scania: *Örkelljunga, Perstorp, Hässleholm, Höör and Hörby*.

Örkelljunga Municipality has around 10,000 residents. On their website, one can read that Örkelljunga Municipality has two treatment plants[29]. One in Skånes Fagerhult, which serves the urban area and its norther sections, while Örkelljunga treatment plant accepts wastewater from the towns of Eket, Örkelljunga, Åsljunga and Skånes Värsjö. No definitive volumes of wastewater have been able to be found, but on the website, it states that in Örkelljunga treatment plant around 2,000-5,000 m^3 wastewater is treated every day. A low estimate thereby yields that at least 730,000 m^3 wastewater/year is treated, which corresponds to a pharmaceutical emission of around 2.7 kg.

Perstorp Municipality has more than 7,000 residents. No information on the treatment plant could be found on their website[30].

Hässleholm Municipality has almost 52,000 residents. Their water is treated by Hässleholms Vatten AB which has a detailed overview of their treatment plants on the website[31]. Based on Environmental Reports 2016 and other information, the total volume of treated wastewater can be calculated as per **Table 9**.

Table 9. *Estimate of annual amount of emissions of 21 pharmaceuticals in Hässleholm Municipality based on available Environmental Reports 2016 from Hässleholms Vatten AB and on the relationship between the volume of treated wastewater in thousands of m³/year and emissions of pharmaceuticals in kg/year as per Figure 12.*

Treatment plant	Volume m^3/day	Volume m^3/year	Volume thousands m^3/year	Amount pharmaceuticals kg/year
Hässleholms TP, Hässleholm	-	4,338,940	4,339	16.3
Emmaljunga TP	200	73,000	73	0.3
Vittsjö TP	-	46,558	47	0.2
Verums TP	8	2,920	3	0
Mölleröds TP	8	2,920	3	0
Hästveda TP	-	217,155	217	0.8
Farstorps TP	14	5,110	5	0
Röke TP	39	14,235	14	0.1
Hörja TP	24	8,760	9	0
V Torups TP	60	21,900	22	0.1
Attarps TP	8	2,920	3	0
Vinslövs TP	-	247,719	248	0.9
Nävlinge TP	40	14,600	15	0.1
N Mellby TP	10	3,650	4	0
Sösdala TP		623,491	623	2.3
Total:		**5,623,878**	**5,624**	**21.1**

Hässleholm Municipality discharges approx. 21 kg of pharmaceuticals.

Höör and *Hörby* municipalities together have almost 32,000 residents. Their water is treated by Mittskåne Vatten. On their website, it states that they today have 10 treatment plants in varying sizes, of which six are located in Hörby Municipality and the remaining four in Höör.[32] Otherwise, there was no information on volumes of treated wastewater. This study included Ormanäs treatment plant, which discharged 6.2 kg of pharmaceuticals. The actual amount for Mittskåne

29 http://www.orkelljunga.se/16/bygga-bo-och-miljo/vatten-och-avlopp.html

30 http://www.perstorp.se/kommunalt_vatten_och_avlopp.html

31 http://www.hassleholmsvatten.se

Vatten is, however, larger but is not calculated further here due to a lack of information. Altogether, the emission in Central Scania's water is estimated at 2.7+21.1+6.2 = 30.0 ~ **30 kg**/year of these 21 pharmaceuticals.

8.7 Summation of estimated emissions of pharmaceuticals to Scania's recipients

It is important to establish that the estimates given below are only estimates that build on information available through the municipalities' websites or, where applicable, links to environmental reports that were relatively easy to access. Moreover, several treatment plants are not included in the calculation, due to a lack of information. Another aspect is that some treatment plants must sometimes brim their treatment plant's wastewater, which then runs untreated out into the recipient. It also does not take into account private sewage where many of them probably load various recipient types. One should also take into account that this study only includes a very limited selection of substances out of several hundred potentially occurring active medications on the market that are consumed and also end up in our wastewater.

The summed amount of pharmaceuticals of the 21 substances included in the LUSKA project ends up at 569 kg/year in our estimation, **Table 10**.

Table 10. *Estimate of total annual amount of emissions of 21 pharmaceuticals in Scania based on available information on volumes of wastewater in various areas of Scania and on the relationship between volume of treated wastewater in thousands of m^3/year and emissions of pharmaceuticals in kg/year as per Figure 12.*

Area in Scania	Amount pharmaceuticals in kg/yr
North-west	160
South-west	275
South	46
South-east	11
North-east	47
Central	30
Total	**569**

This load of 569 kg is visualised in **Figure 26**. However, it is not at all unreasonable with the following reasoning to imagine a total pharmaceutical load to Scanian waters regarding all occurring (but not analysed substances) of at least twice as much, so >1000 kg/year, but probably significantly more than this.

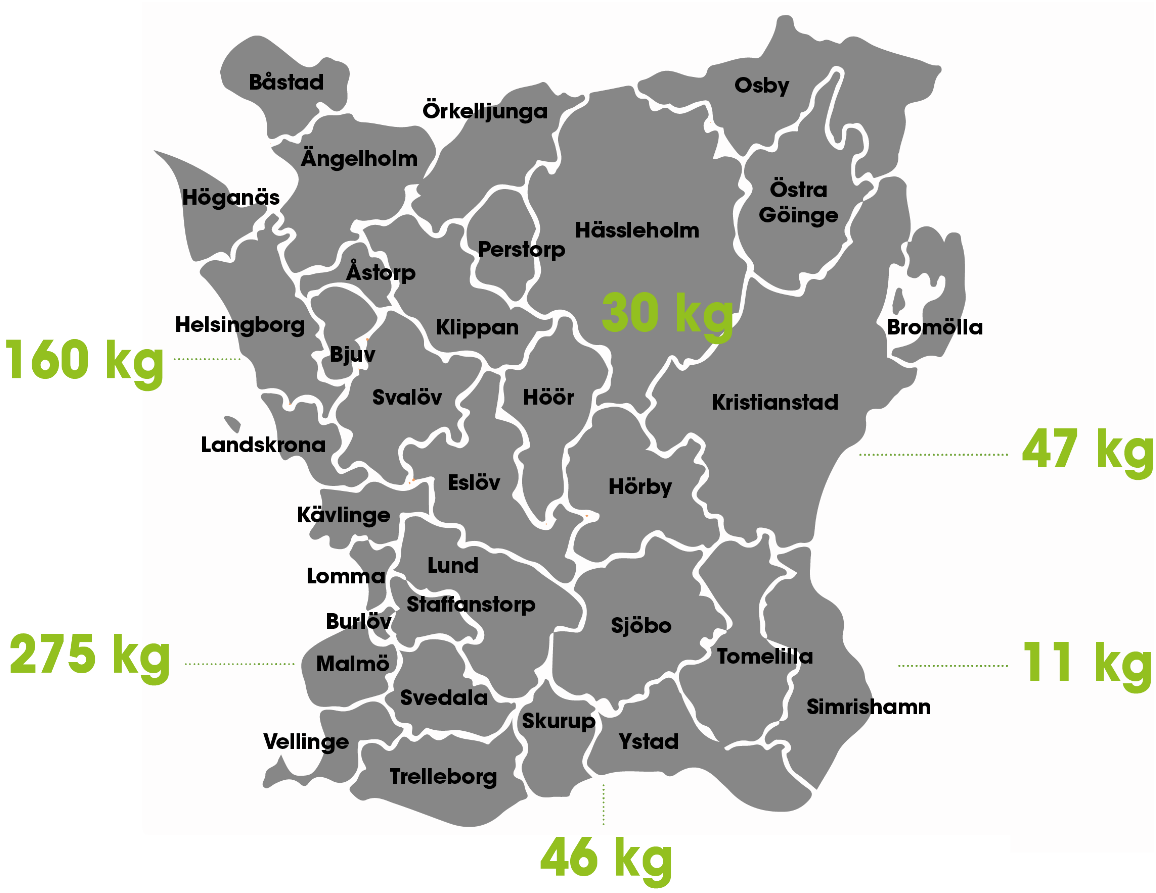


Figure 26. *Visualisation of the released amounts of pharmaceuticals of 21 medications as per the Swedish Medical Products Agency's watchlist in various parts of Scania based on calculations compiled in Table 8.*

9. How should we upgrade the treatment plants in future years?

In 2016, the Swedish Environmental Protection Agency was assigned by the Government to investigate the conditions for the use of advanced treatment with an aim of separating drug remnants and microplastics from Swedish wastewater[32]. The report was published at the end of April 2017 and there, it is established that pharmaceutical emissions can be prevented by equipping the treatment plants with more advanced technology, such as carbon filters or ozone treatment. Today, there is a lack of Swedish treatment plants with such technologies. The Swedish Environmental Protection Agency also states in the report that one now needs to go on to investigate where the technology should first be introduced and how it should be financed. The question is whether it is the large treatment plants, the smaller treatment plants or if it is treatment plants on watercourses that are most sensitive that should be improved first? The following investigative text is also presented in the report:

> *"At which and how many wastewater treatment plants is there a need of advanced treatment cannot be specified with the existing data, but factors that have a major significance to prioritising where the efforts need to be made have been identified. In the implementation of supplemental treatment steps for drug remnants and other undesired substances, consideration must be made of local conditions, such as:*
>
> - *The amount of drug remnants and other persistent pollutants that are discharged into the recipients.*
> - *The recipient's water turnover, where the recipients with low initial dilution and low water turnover are at risk of achieving levels that are in the assessment grounds for especially polluting substances (SFÄ) and effect levels*
> - *Several treatment plants with discharge to the same recipient*
> - *The recipient's sensitivity, such as e.g. ecological sensitivity*
> - *Variations over the year in "water turnover" in the recipient and*
> - *Variations in discharge amounts from the treatment plant*

The Swedish Environmental Protection Agency's report also states the following:

> *"The need to introduce advanced treatment at treatment plants varies and we do not know today how many or which should be prioritised. It is also desirable to ensure a knowledge build-up and sustainable implementation of advanced treatment since this is under development, such as through gradual introduction. The Swedish Environmental Protection Agency proposes that the Government have an investigation done of continued steps in a direction toward introduction of advanced treatment beginning with where the need is the greatest.*
>
> ***Step 1:*** *Investigate which wastewater treatment plants have the greatest need to introduce advanced treatment of drug remnants*
>
> ***Step 2:*** *Investigate what governance can lead to advanced treatment being introduced where the need is the greatest in a socioeconomically effective and suitable manner.*

The LUSKA project is a Scanian initiative that answers some of these questions to a number of local treatment plants and recipients. The hope is to continue investigating where measures need

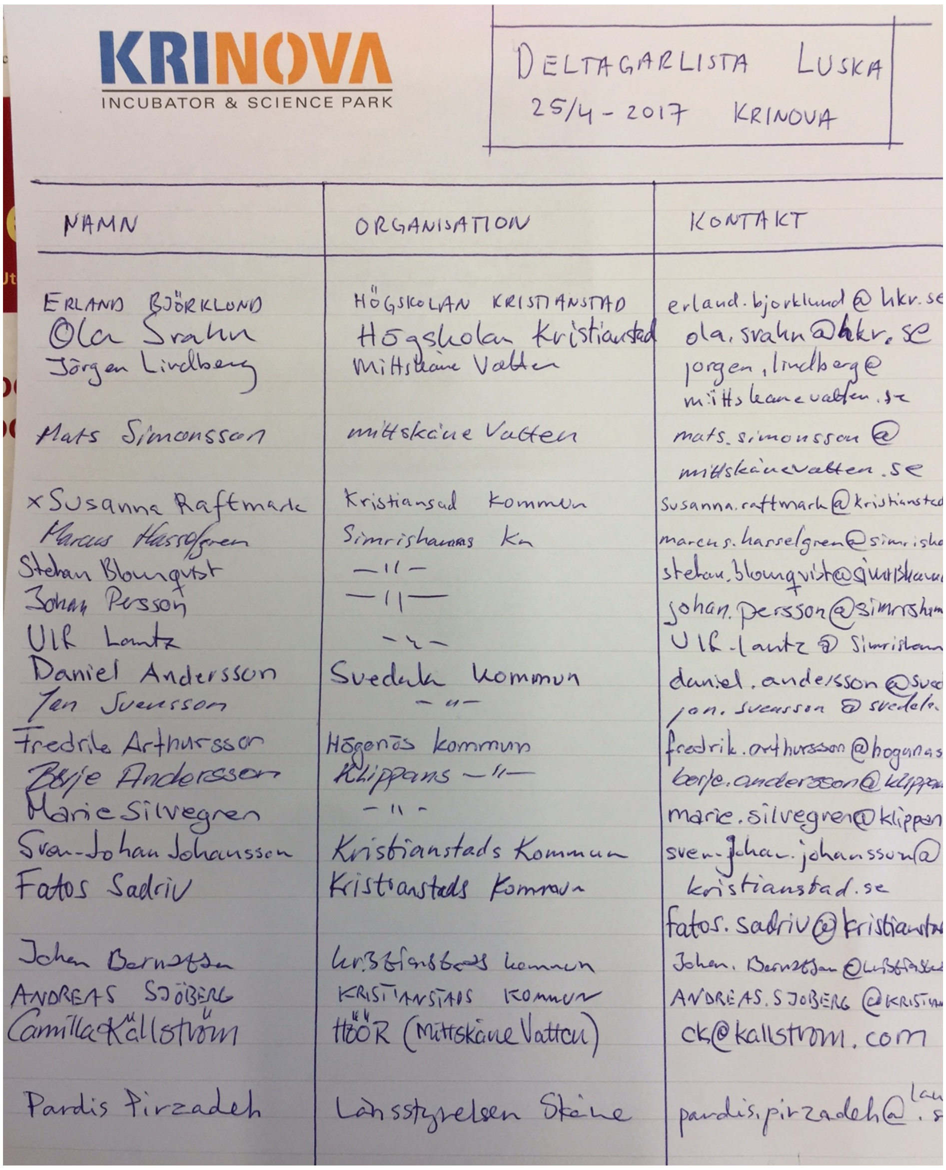
[32] Avancerad rening av avloppsvatten för avskiljning av läkemedelsrester och andra oönskade ämnen- Behov, teknik och konsekvenser [Advanced treatment of wastewater for separation of drug remnants and other undesired substances - Needs, technology and consequences] - Report 6766 • APRIL 2017, Reporting of Government assignment. Swedish Environmental Protection Agency, 88 pages.

to be applied most of all, from a Scanian perspective in collaboration between both municipal wastewater treatment organisations and authorities at various levels. The vision is that the result may also be applied at a national level.

Probably as a consequence of the Swedish Environmental Protection Agency's report, the Government announced that it is investing SEK 5 million per year over three years beginning in 2018 with the aim of creating a *Centre for Pharmaceuticals and the Environment*. This centre will distribute knowledge and promote dialogue and cooperation regarding the environmental effects of pharmaceuticals and be under the Swedish Medical Products Agency. In addition, the Government is giving SEK 45 million to the municipalities that want to invest in pharmaceutical treatment in 2018, while another SEK 50 million will be added in 2019 and SEK 70 million in 2020 for advanced treatment of wastewater.

With continued concerted efforts by municipalities, regions, companies and the academic community, Scania has a unique opportunity with its relatively large population (1.3 million residents) and large amount of sensitive recipients of a high conservation value in the form of rivers, lakes and surrounding salt and brackish seas to become a pioneer in aquatic sustainability thinking to benefit future generations.

Appendix 1



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Appendix 2. *Inlet concentrations in ng/L of 21 pharmaceuticals from seven Scanian treatment plants. In this table, the treatment plants and the pharmaceuticals are listed in alphabetical order.*

ng/L	Gärds Köpinge	Höganäs	Klippan	Kristianstad	Ormanäs	Simrishamn	Svedala
Ciprofloxacin	48	704	511	526	871	304	758
Citalopram	157	240	125	622	247	188	341
Clarithromycin	0	106	93	112	171	47	293
Diclofenac	768	827	486	805	493	654	1059
Erythromycin	0	70	33	686	8	140	536
Estrone	57	49	64	12	44	56	68
Fluconazole	1	37	24	68	44	15	29
Ibuprofen	25,016	34,748	29,383	4,939	36,506	9,567	37,144
Carbamazepine	57	406	502	528	479	1179	633
Ketoconazole	12	109	36	305	51	64	122
Levonorgestrel	0	0	0	0	0	0	0
Losartan	615	641	269	528	84	548	902
Metoprolol	747	2196	940	1,123	785	917	1426
Methotrexate	2	4	16	4	14	1	5
Naproxen	2,859	2,157	2,575	4,353	1888	1059	2,549
Oxazepam	88	406	316	418	300	275	334
Sertraline	66	92	54	247	103	55	173
Sulfamethoxazole	63	460	141	625	230	141	624
Tramadol	201	182	205	265	132	79	155
Trimethoprim	11	104	30	95	59	28	113
Zolpidem	2	5	1	6	2	2	7

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