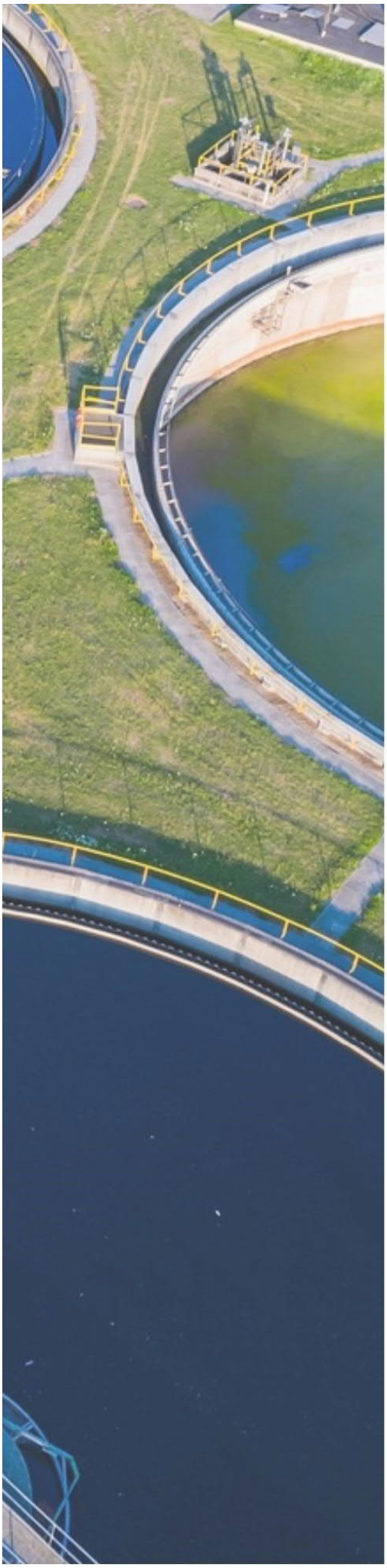

Interreg South Baltic

EUROPEAN UNION

European Regional Development Fund

Less is More

less is MORE

Energy-efficient technologies for removal of pharmaceuticals and other contaminants of emerging concern

Deliverable 4.3

Joint and consolidated evaluation report

Foreword

This report is part of the project LESS IS MORE - Energy-efficient technologies for removal of pharmaceuticals and other contaminants of emerging concern. The project has been financed by the Interreg South Baltic Programme 2014-2020 through the European Regional Development Fund. The Swedish partners' participation in the project was co-financed by the Swedish Agency for Marine and Water Management.

Partners in the project are: Lund University, Department of Chemical Engineering; Sweden Water Research AB, Kristianstad University, Slagelse Utility, Slagelse Municipality, JSC "Kretinga Water" and Gdansk Water Fund.

The project started 1st of January 2018 and completion date is 30th of June 2021.

The specific project objective is to pilot -demonstrate, test and validate - new technological solutions, for removing pharmaceuticals and other CECs as well as antibiotic-resistant bacteria, that are suitable for small and middle sized WWTPs and to disseminate information on new technologies to the end-users.

This joint and consolidated evaluation report summarizes the project outcomes, both technical and communicative results. It summarizes the experiences from operation of the three demonstration plants in pilot-scale in respect of treatment efficiency as well as cost, energy demand, and technical feasibility but it also includes information about all external communication activities performed during the project.

This report was written by Michael Cimbritz and Åsa Davidsson but is the result of the activities involving all partners in the project.

The contents of this report are the sole responsibility of the author[s] and can in no way be taken to reflect the views of the European Union, the Managing Authority or the Joint Secretariat of the Interreg South Baltic Programme 2014-2020.

Lund, June, 2021

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1. Overall project results

The project has resulted in a successful fulfillment of the main outputs and deliverables. More information about the planned and realized outcomes is summarized below.

Objective

The objective of the project has been to pilot - demonstrate, test and validate - cost-effective technological solutions, for removing pharmaceuticals and other CECs as well as antibiotic-resistant bacteria, that are suitable for small and middle sized WWTPs.

Project result

The project has resulted in increased knowledge and availability of validated removal technologies with respect to energy efficiency, technical feasibility and cost-effectiveness, developed in close cooperation with the end users notably the small and medium sized municipal WWTPs.

Project deliverables

A list of all the deliverables and connected outcomes is found in Table 1.

Table 1. Deliverables and outcomes from the LESS IS MORE project.

Deliverables	Outcomes
3.1	Peer review report
3.2	Pilot units installed and in operation: Drawings, pictures etc, see Chapter 2 and National reports (Del 4.1)
3.3	Concept design and investment proposal Swedish case report - Svedala Concept design and investment proposal Polish case report - Słupsk
4.1	Specific expert papers on treatment technology/efficiency: Part I: National Swedish report on the Svedala pilot plant Part II: National Danish report on the Slagelse pilot plant Part III: National Lithuanian report on the Kretinga pilot plant Part IV: Consolidated summary on treatment efficiency results
4.2	Specific expert papers for enhanced reuse of end products: Water re-use report (included in the National Danish report) Energy re-use report
4.3	Joint and consolidated evaluation report

Project main outputs

The LESS IS MORE project had two main outputs (MO) described below and in Table 2.

MO1: Separation technologies focusing on membrane and activated carbon processes used in various combinations piloted, tested and validated based on energy and cost efficiency. Three pilot units for testing different treatment process - designed, constructed and installed at three WWTPs in Sweden, Denmark, and Lithuania.

MO2: Two (2) different setup's for polishing steps with activated carbon will be developed. One with membrane/microfiltration prior the activated carbon filter and one without any filtration before the carbon filter. One (1) treatment technology solution developed where the membrane and carbon filters are introduced early in the process i.e. before the polishing step, allowing combined production of renewable energy from biomass. One (1) overall evaluation report presenting and comparing the technologies with respect to the following criteria: environmental performance, energy efficiency, technical feasibility & cost-effectiveness (See Chapter 2).

Table 2. Description of main outputs (MO1 and MO2) with target groups and outcomes.

Outputs		Realized outcomes (targeted value in parenthesis)
MO1 target group	WWTPs in small and medium coastal municipalities. Currently, most WWTPs do not have the capacity to remove micro-pollutants. As a first step, these organisations need improved access to well-documented, cost-efficient and robust technologies to, in the second step, upgrade the WWTPs.	32* (13)
MO1	Pilot investments in technological solutions for removing pharmaceuticals and other CECs as well as antibiotic-resistant bacteria. [unit:] €	301 180 EUR (304 000 EUR)
MO2 target group	MO2 target group: Target groups and needs. Coastal municipalities and WWTPs need improved knowledge for investment planning. R&D organisations, SME associations and SMEs for R&D. National water and environmental authorities, National water associations, EU water sector platforms, HELCOM and Env. NGOs – to inform policy and standards.	63**(40)
MO2	MO2: At least three removal technology solutions developed and presented in the form of blue prints and expert papers. [unit:] Number	3 (3)
	No. of delivered green technology services, products, standards and tools	3 (3)
	Size of pilot investments co-financed by the Programme in the uptake of green technologies	301 180 EUR (304 000 EUR)

* Based on the number of hosting WWTPs and the number of municipalities participating in the national demonstration events organized in Denmark (Slagelse 17 Jan 2020) and Sweden (Lund 15 Dec 2020).

** Based on the number of participating organizations (Municipalities, R&D org./Universities, Consultants, SMEs and Technology suppliers, National Authorities, National Water associations, EU water platforms, Environmental NGOs) in the national events in Denmark and Sweden and the EUSBSR PA Hazards' BSR-Pharma Platform event 19 Sep 2019. More info about these events can be found in Chapter 3.

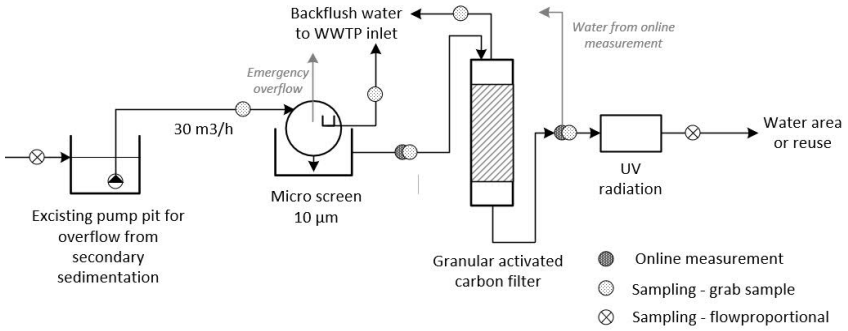
2. Evaluation of technologies

Technologies focusing on membrane and activated carbon processes have been applied in different combinations in pilot scale in three countries, Lithuania, Denmark and Sweden, see locations in Figure 1. Full-scale design was the focus in Denmark and Lithuania where GAC filters were installed as a fourth and final polishing step preceded by microsieves. Besides removal of organic micropollutants, reuse of treated wastewater was evaluated in the Danish plant where the GAC filter was proceded by in-line UV-treatment. In addition to GAC as a polishing step, an innovative configuration applying chemical precipitation with microsieving and Direct Membrane Filtration (DMF) on primary wastewater as pre-treatment to GAC filtration was tested in Sweden.

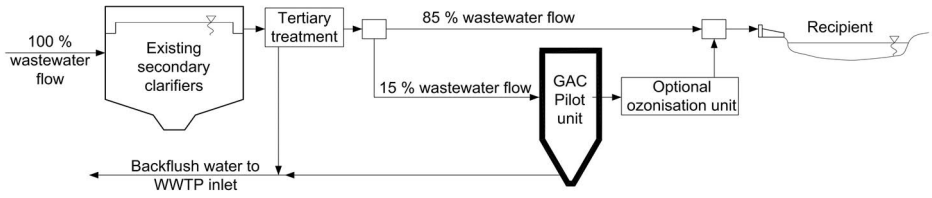
Figure 1. The three pilot plants in the Less is More project, Svedala in Sweden, Kretinga (outside Klaipeda) in Lithuania and Slagelse (on the west side of Sjaelland) in Denmark.

The pilot plant concepts are shown in Figure 2.

Concept for pilot plant in Slagelse, Denmark



Concept for pilot plant in Kretinga, Lithuania



Concept for pilot plant in Svedala, Sweden

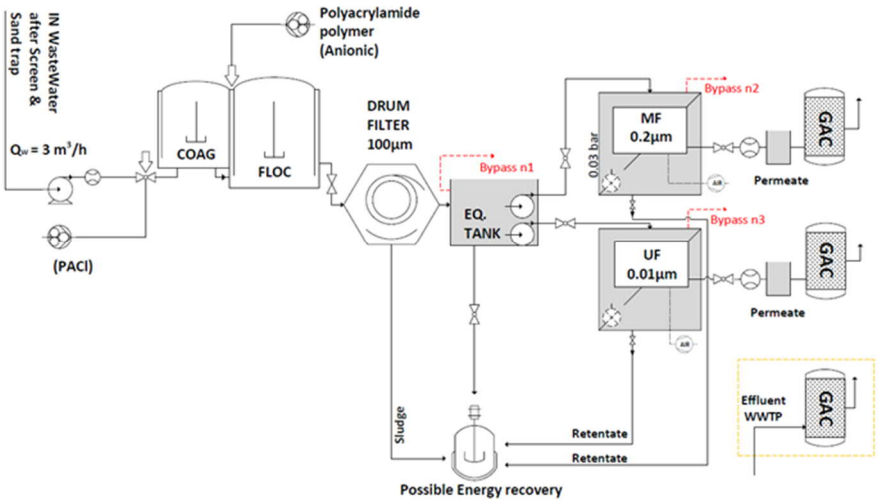


Figure 2. Concept charts for the three pilot plants in Denmark, Lithuania and Sweden.

GAC-filtration as an additional treatment step, after conventional biological treatment, was tested in all pilot plants. The GAC-filters in Slagelse and Kretinga WWTP were preceded by microsieves and the filter at Svedala WWTP by a sand filter. At the Swedish pilot plant Direct Membrane Filtration (DMF)

followed by GAC-filtration, was also tested in a parallel treatment line. The DMF + GAC-line differed from the pilots using GAC as polishing step since the GAC-filter was loaded with water that had not passed biological treatment, which influences the organic content and the characteristics of the organic matter. Both microfiltration (MF) and Ultrafiltration (UF) were tested in parallel.

The large-scale pilot plants in Lithuania and Denmark are permanent installations and will be in operation also after the finalization of the LESS IS MORE project allowing for continued visits and collection of data and operational experiences.

Analysis of pharmaceuticals and other contaminants of emerging concern

A project-wide analysis capacity of organic micro-pollutants, through MoLab, Kristianstad University, has made it possible for all samples to be analyzed in the same way. MoLab is a state-of-the-art advanced organic trace-analysis laboratory equipped with a high-end UPLC-MS/MS. The innovative sample preparation techniques and developed analytical methods enable whole water analysis at low limits of quantification (LOQs) with high precision for a wide range of contaminants. In this project about 35 micropollutants were selected for analysis. Figure 3 shows sum of concentrations of 14 critical substances. These substances were all measured in concentrations higher than the $PNEC_{Freshwater}$ (Predicted No Effect Concentration) in the effluent of the WWTP.

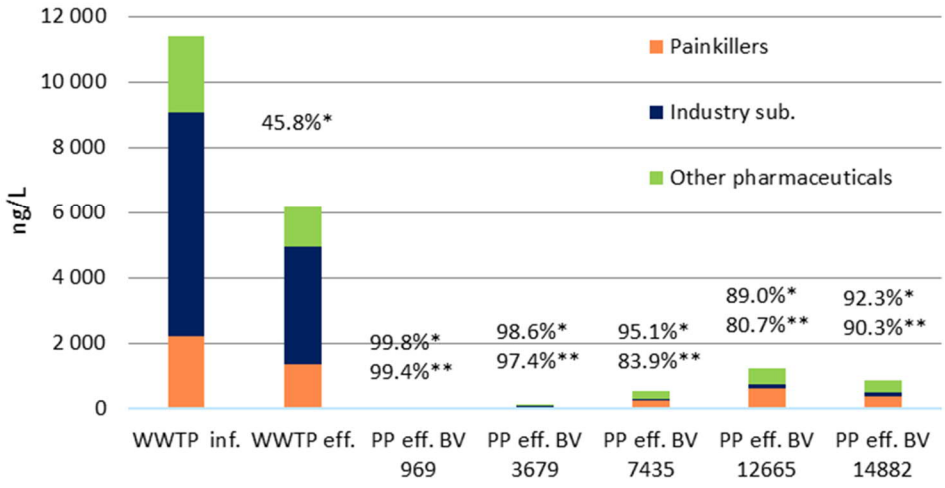


Figure 3. Sum of concentration of 14 critical micropollutants at Slagelse WWTP in the influent, effluent and at increasing operational time (number of bed volumes, BV) at the Pilot Plant.* Reduction of total concentration relative to WWTP inf. ** Reduction relative to WWTP eff.

The removal of these 14 substances was relatively low in the conventional WWTP (< 50%). High removal was observed after the pilot plant treatment. With fresh GAC (BV 969), a removal of >99% was measured, and after BV 12,665 a total removal rate of 86.4% was observed from inlet of the conventional WWTP to outlet of the pilot plant.

Techno-economic outcomes

The feasibility of the investigated technical solutions has been evaluated and can be summarized as the following techno-economic outcomes:

GAC filtration is a feasible option for removal of contaminants of emerging concern. Operation is straightforward and post-treatment with GAC can be readily added following biological treatment and pre-filtration. More findings on GAC:

- The technical feasibility and cost effectiveness have been demonstrated at three different small- and midsized WWTPs during long-term operation in full-scale.
- Project results can facilitate future designs and have shown that GAC-filtration can be installed at a cost of approximately 0.1 €/m^3 including capital and operational expenditures.
- UV-treatment can be added to remove antibiotic resistance and pathogens in order to enable water reuse.
- Environmental performance can be improved using regenerated carbon.

Direct membrane filtration followed by GAC treatment doesn't exhibit the same technology readiness level as GAC for post-treatment. Pre-treatment to DMF, based on coagulation/flocculation and microsieving, shows high potential for energy recovery.

3. Events and other external communication

Besides using written material like expert papers and reports for dissemination of information about the project and its findings, different kinds of events were arranged throughout the project time, e.g. demonstration events at pilot plants, local events for stakeholders in Poland and other open events. The project targets two groups of organizations:

MO1 target group: WWTPs in small and medium coastal municipalities.

MO2 target group: Coastal municipalities and WWTPs, R&D organizations, SME associations, SMEs for R&D, national water and environmental authorities, national water associations, EU water sector platforms, HELCOM and Env. NGOs.

The targeted organisations have, through the LESS IS MORE project got access to information about the technologies studied by pilot-scale demonstration units in various ways. Some of the information activities were the below described events.

Local events for Polish stakeholders

Polish stakeholder local events were held on-line at three occasions attracting a high number of participants from Polish municipalities, see Table 3.

Table 3. Information about Polish local events

Date	Presenters	Participants	Description
9th of March	LP, PP3, PP4, PP5, PP6 and PP7	In total 80 participants, with representatives from coastal municipalities and WWTPs (70%), universities/R&D (28%) and national water and environmental authorities (2%).	The project and the three pilot plants including preliminary results were presented as well as the Słupsk case study.
21th of May	LP	In total 90 participants from universities, water and environmental authorities, water utilities and private companies.	The Less is more project was shortly presented within the MonGOS project workshop.
8th of June 2021	LP, PP3, PP4, PP5, PP6 and PP7	In total 42 participants , with representatives from coastal municipalities and WWTPs (>80%), universities/R&D (10%) and the rest from national water and environmental authorities and private companies related to the water sector	Information about the project and results from the three pilot plants were presented together with a preliminary Polish concept design in a 1.5- hour-seminar.

National Danish demonstration event

Slagelse Utility (SK Forsyning) and Slagelse Municipality (PP4 and PP5) together with DHI arranged a ”visitors day” 17 January 2020 for the project “Less is More”. This event was organized to show participants how Slagelse Municipality and SK Forsyning test new wastewater treatment methods for removal or pharmaceutical residues, resistant bacteria and other CECs.

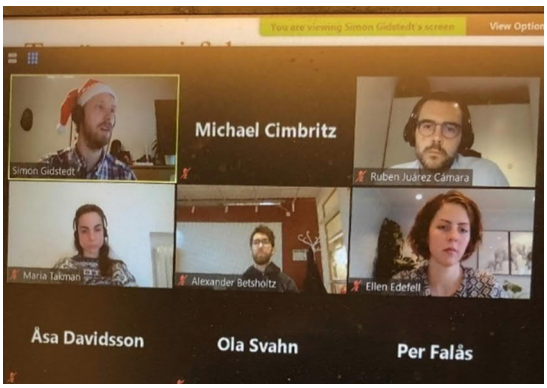
The arrangement was an opportunity for invited quests to hear about the project and to see the pilot plant, and also an opportunity to ask a lot of questions. In all, 42 participants representing different kinds of organizations were present (municipalities and WWTPs, regional health-care institutions, SMEs within R&D, local and regional authorities and environmental NGOs).

Figure 4. Demonstration event at Slagelse WWTP with 42 participants.

National Swedish event

Due to the pandemic restrictions, a physical demo event at the pilot plant was replaced by a digital 3-hour-seminar on the 15th of December 2020 arranged by Lund University (LP) in collaboration with Kristianstad University (PP3) and Sweden Water Research (PP2). The seminar was highly appreciated, more than 100 participants from foremost Swedish and Danish stakeholders attended, including representatives from coastal municipalities and WWTPs, R&D organizations, SME associations, SMEs for R&D, national water and environmental authorities, national water associations, and environmental NGOs.

The presentations included e.g. introduction of the LESS IS MORE project in general, the idea of direct membrane filtration in combination with carbon, degradation and adsorption in a GAC-filter, water re-use potential after GAC-filtration and development of analysis methods.



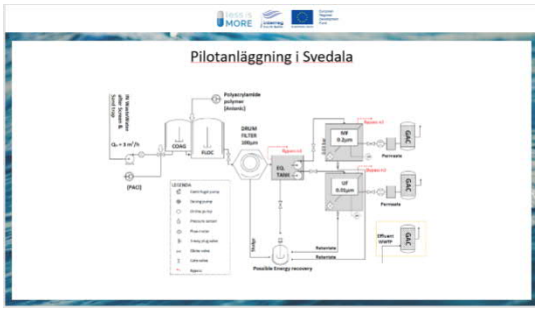


Figure 5. Digital event arranged in Lund on 15th of December 2020.

Other events

In the Table 4, other occasions were the LESS IS MORE project have been presented are listed. Various type of events with attendants representing many different organizations – from public to authorities – have been used for communicating the project.

Table 4. List of other events including LESS IS MORE project presentations.

Type of event	Date and place	Presentation (partner)	Participants
MORPHEUS third partner meeting	Essen, Germany, April 2018	Project presentation (PP3)	MORPHEUS partners
Interreg South Baltic Annual event	Klaipeida, May 2018	Project presentation (PP3)	Participants from other Interreg SB projects
Part of the event "European Researchers' Night"	Vattenhallen Science Centre, Lund, 28th to 29th Sept 2018	Short popular science presentations about organic micropollutants in wastewater (LP, PP2)	300 + 100 persons, highs school students and from public
Presentation during The 6th IEA-Vanrolleghem Modelling Seminar	IEA, Faculty of Engineering, Lund University, Sweden, August 29, 2018	Project presentation (LP)	Around 30 participants from academia and companies in Sweden, Denmark and Canada
Meeting with Svedala municipality (hosting the pilot)	Lund University, 31 August 2018	Presentation of the project with focus on the Swedish pilot part (LP, PP2)	9 persons

Sweden Water Research Day	30th Nov 2018 in Malmö	Presentation about the project as a whole and more in detail regarding the pilot in Svedala (LP, PP2)	200 people attended; e.g. representatives from research, utilities, private companies and, authorities
Meeting about research within micropollutant l	Veolia Water Technologies, Lund, January 8th 2019	LESS IS More project presentation (LP, PP2)	15 persons, mainly from the company
Seminar on research activities on micropollutants	Lund University, January 14th 2019	Project presentation (LP)	25 persons from municipal, academic and commercial organizations.
Interreg SB STEP partner meeting	Höör, Sweden, February 26th 2019	Project presentation at our "sister project" meeting (LP)	About 10 persons from the STEP project
Training on advanced wastewater treatment	Sweco, Malmö, March 6th 2019	Presentation of project (LP)	10 consultants at Sweco
MIRAI Sustainability Workshop	March 28-29th, 2019, University of Technology, Tokyo (Japan)	Presentation of the project at MIRAI, a seminar to connect Swedish and Japanese research (LP)	Around 100 persons, mainly from Japanese and Swedish universities
Engineering with Membranes Conference, Båstad, Sweden	8-10th of April 2019 in Båstad, Sweden	Poster presentation about project with focus on Swedish pilot plant. (LP)	170 persons working in the membrane area
Presentation at two post-graduate courses	SLU in Uppsala, Sweden. 2018-11-07 and Luleå 6-10 April 2019	Project presentation (LP, PP2)	20 + 15 persons from different Swedish universities
Demonstration event at Svedala pilot plant	9th of May 2019	Demonstration of pilot plant (LP, PP2)	8 persons from Svedala municipality
Presentation and lecture for master students at Hiroshima University	Hiroshima University (Saijo, Hagashi-Hiroshima, Japan) - June 2019	Presentation about the project as part of lecture. (LP)	30 students and 3 professors
Internal meeting Sweden Water Research	Tiraholm by lake Bolmen in Sweden. 4th of June 2019.	Project presentation (LP, PP2)	17 persons from PP2
Event within "sister project" MORPHEUS	28-29th of June 2019 in Gdansk	Project presentation and preliminary results from Slagelse pilot plant (LP, PP4, PP5, PP7)	Participants from the Morpheus project.

EUSBSR PA Hazards' BSR-Pharma Platform	Stockholm, 19th Sept, 2019	Project presentation (LP, PP3, PP7)	Over 20 persons from different organizations including authorities, waster associations, EU platforms and NGOs.
Presentation during the conference NORDIWA 2019	Helsinki, Finland 23-25 September 2019	Project presentation (LP, PP2)	Over 100 persons from different water organizations
Training courses organized in Poland at different times and places.	2019: 11 April, 25-26 April, 21-23 May, 4 June, 6-7 June, 8 June, 7-13 July, 22 August, 17-18 September.	Short information about the project at several occasions, see Table 5	Participants from water related organisations.
XXII Kongres Naukowo - Techniczny WOD-KAN-EKO	14th of Nov 2019 in Łódź	Project presentation (PP7)	Polish stakeholders
Morpheus project final meeting	Lund, December 2019	Project presentation (LP, PP3, PP7)	Open meeting with >50 participants from different organizations
DANVA on-line meeting	18th of May, 2020, online	Project presentation with focus on Slagelse pilot (PP4)	101 persons from Danish water utilities
National seminar, Envisys höstmöte	18th Nov, 2020 in Lund/on-line	Presentation of Svedala pilot results (LP, PP2)	Swedish water companies and utilities (>150 persons)
DANVA webinar	12th May 2021	Project presentation (PP4, PP5)	Danish water organisations
Internal Sweden Water Research seminar	21st of May, 2021, digital event	Project presentation (PP2)	40 persons from municipal water utilities
Midway seminar Alexander Betsholtz	27th May, 2021 online	Presentation of results from supplementary tests	>40 persons from academia, water utilities and private companies
Midway seminar Simon Gidstedt	16th june, 2021 online	Presentation of results from the Swedish pilot plant	>35 persons from academia, water utilities and private companies

Polish training courses

During the project a lot of effort has been on informing Polish stakeholders about the project. Besides the events mentioned previously, Gdansk Water Fund (PP7) has used several Polish training

courses for dissemination of the LESS IS MORE project. A list of some of the events is found below (Table 5).

Table 5. List of Polish training events during Oct 2019-Mar2020 which were used for dissemination of the project through short presentations and flyers.

Event in Polish	Event in English	Nb of partici-pants
Procesy technologiczne na obiekcie basenowym	Technological processes at the swimming pool facility	11
Najważniejsze obszary eksploatacji i funkcjonowania systemów wodno-ściekowych	The most important areas of exploitation and functioning of water and sewage systems	12
TAPLING 2019	TAPLING 2019	19
Woda z pływalni 2019	Swimming pool water 2019	21
Nowelizacja normy PN (omówienie zmian z uwzględnieniem potrzeb dostosowania systemu zarządzania)	Amendment of the PN standard (discussion of changes taking into account the needs of adjusting the management system)	7
Ustawa o odpadach – zmiany i wynikające obowiązki dla przedsiębiorców	Waste Act - changes and resulting obligations for entrepreneurs	11
Zasady higieniczne prawidłowego sprzątania na obiekcie basenowym	Hygienic rules for proper cleaning in the swimming pool facility	14
Najważniejsze obszary eksploatacji i funkcjonowania systemów wodno-ściekowych	The most important areas of exploitation and functioning of water and sewage systems	12
Zarządzanie ryzykiem w zaopatrzeniu w wodę analiza ryzyka dla ujęcia wody i ocena ryzyka dostaw	Water supply risk management risk analysis for water intake and supply risk assessment	16
Zarządzanie bezpieczeństwem na wyznaczonych obszarach wodnych z perspektywy ratownictwa wodnego na obiekcie basenowym w Kaliszu	Safety management in designated water areas from the perspective of water rescue at the swimming pool facility in Kalisz	15
Szkolenie z elementami warsztatowymi z eksploatacji na obiekcie basenowym w Kaliszu	Training with workshop elements in operation at the swimming pool facility in Kalisz	14
Ustawa o odpadach – zmiany i wynikające obowiązki dla przedsiębiorców	Waste Act - changes and resulting obligations for entrepreneurs	12
Biologiczna analiza osadu czynnego w praktyce użytkowania reaktorów biologicznych	Biological analysis of activated sludge in the practical use of biological reactors	16
BDO – Podstawy prawne, wymogi, elektroniczna ewidencja odpadów-szkolenie z warsztatami	BDO - Legal basis, requirements, electronic waste records - training with workshops	18
Wymagania w laboratorium chemicznym seminarium doskonalące	Requirements in the chemical laboratory. Improvement seminar	17

In addition, the following training courses were used for dissemination during the period April-September 2020:

- 26th March, E-21 Crisis management of the municipal sewage treatment plant
- 16ht April, E-24 Automatic and remote operation of the treatment plant
- 19th May, E-33 Prevention and elimination of the problem with odors in the sewage network
- 27th May, E-35 Optimization of biological processes in the SBR sewage treatment plant
- 13th May, E-36 Modern methods of aeration control (oxygen concentration and aeration installation) in a sewage treatment plant
- 7th May, E-37 Kawa Wod-Kan - discussion forum of wod-kan companies - on-line

- 23rd June, E-51 Municipal sewage treatment plants - catchment management, sewage monitoring, costs
- 9th-11th Sept, XXIII Swimming-pools seminar

Future events

International scientific conferences were postponed due to COVID-19 pandemic at the end of the project period, but the intention is still to present results from the project. Three presentations are to be held at the NORDIWA wastewater conference online 28 September – 1 October 2021:

- ”Direct membrane filtration followed by granular activated carbon filtration for wastewater treatment” by Simon Gidstedt.
- “Tracking 14C-labeled micropollutants to separate degradation from adsorption in carbon filters” by Alexander Betsholtz
- “Tracking the adsorption profiles of organic micropollutants in a granular activated carbon filter” by Ellen Edefell.

In addition, several abstracts will be sent for potential presentations (if accepted) at the 12th Micropol & Ecohazard Conference in 2022.

The pilot plants in Slagelse and Kretinga are permanent infrastructure and will thus be available for potential future demonstrations event.

Audiovisual material

Two films were produced as information material and they are available through the links below.

- A film about the Lithanian pilot plant in Kretinga is found through the project web site GFW - Gdańska Fundacja Wody
- Sweden water research project website including film about the project - https://www.swedenwaterresearch.se/projekt/less-is-more/

Other written communication

Other communication of the project and achieved results has been done through newsletters, reports, articles and scientific publications, see below:

- Newsletter for Swedish stakeholders (about 150 persons from municipal, academic and private organisations) through the VA-teknik Södra network, June 2018
- Sweden Water Research Annual report 2019 - Pilotanläggning för läkemedelsrening på Svedala avloppsreningsverk - Sweden Water Research
- Article 28 August 2018 in Danish newspaper - http://www.zealanddenmark.eu/blog/nyhed/saadan-skal-eu-stoette-goere-sjaellandsk-spildevand-endnu-renere/

- Article published in BMP 2/2020 Pharmaceutical Industry magazine, "Pharmaceuticals and the aquatic environment. Threats, removal technologies, EU projects".
- Article in the e-journal WaterTech, 23 Feb 2021
- Two articles in the Danish publication Spildevand (page 48-50 and 59), https://issuu.com/spildevandstekniskidsskrift/docs/spildevand_2_2021web
- Other project informative material (flyer, roll-up, newsletters) are found in the project website - GFW - Gdańska Fundacja Wody
- Article 26 May 2020 in the Lithuanian newspaper, Pajūrio naujienos, "Diegia technologiją vaistams ir kitiems teršalams šalinti", see Figure 6 (English translation: Implements technology to remove drugs and other contaminants), UAB Pajūrio naujienos (pajurionaujienos.com)
- Four scientific papers (published or to be published after scientific reviews):

  Betsholtz, A., Karlsson, S., Svahn, O, Davidsson, Å. , Cimbritz, M., Falås, P. ^{14}C-Labeled Organic Micropollutants to Differentiate between Adsorption and Degradation in GAC and Biofilm Processes. Environmental Science and Technology. In press. https://doi.org/10.1021/acs.est.1c02728

  Gidstedt, S., Betsholtz, A., Falås, P., Cimbritz, M., Davidsson, Å., Micolucci, F., Svahn, O. A comparison of organic micropollutants adsorption onto activated carbon following direct membrane filtration and biological treatment of municipal wastewater. [Submitted manuscript] Department of Chemical Engineering, Lund University.

  Gidstedt, S., Betsholtz, A., Karlsson, S., Takman, A., Cimbritz, M., Davidsson, Å., Hagman, M., Micolucci, F. (2021b) Direct membrane filtration in municipal wastewater – A pilot scale study of treatment performance, energy balance and organic micropollutant removal. [Unpublished manuscript] Department of Chemical Engineering, Lund University.

  Edefell, E., Svahn, O., Falås, P., Ullman, R., Cimbritz, M. (2021). In depth of a GAC filter – temporal and spatial profiling of adsorbed organic micropollutants. [Unpublished manuscript] Department of Chemical Engineering, Lund University.

Diegia technologiją vaistams ir kitiems teršalams šalinti

Audronė PUIŠIENĖ Pirmas puslapis 2020-05-26

Bendrovė „Kretingos vandenys“ kartu su tarptautinio projekto partneriais tiria, kaip efektyviai aktyvinti vandens filtrai išvalo nuotekas nuo į jas patenkančių medikamentų. Įmonės nuotekų valyklų technologė Donata Pasovienė paaiškino, kad tokių teršalų šalinimas iš nuotekų nėra išsamiai ištirtas.

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„Šiuo met
miesto nuotek
filtras, kuris tu
sumažinti

Figure 6. Article about the Kretinga pilot plant in a newspaper UAB Pajūrio naujienos (pajurionaujienos.com)

4. Success story

The plant in Slagelse is considered to be the most prominent "success story" of the project. The plant was operated during a substantial part of the project time, and is still in operation as a permanent installation of the wastewater treatment plant. A very high removal of pharmaceuticals and other CECs was the result of the implemented additional treatment (microsieving, GAC-filtration and UV-radiation). In addition the treated effluent complies with criteria from DK drinking water and EU regulation on water reclamation (microbiology). The success story is presented on next page and can also be downloaded at www.gfw.pl/projekty/less-is-more/. The most important takeaways are:

- Overall GAC was effective (≥97%) for removal of analysed micropollutants
- 6 pollutants were breaking through (>PNEC) after 15,000 BV
- The effluent complies with criteria from DK drinking water and EU regulation on water reclamation (microbiology)
- Total cost for full scale implementation is estimated to 0.088 EUR/m^3
- A new follow-up project (Oxytreat) is established to reduce breakthroughs and increase GAC durability

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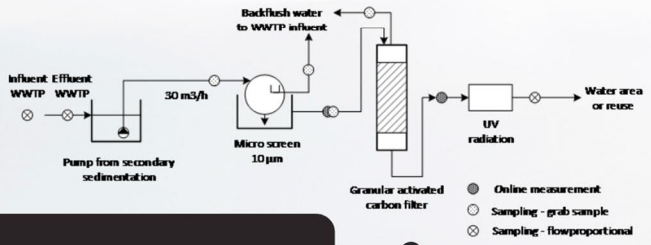
SUCCESS STORY



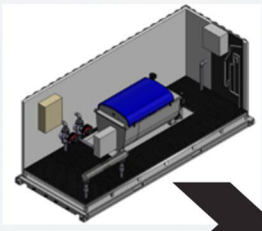
LiM Pilot plant in Slagelse Experiences with GAC and UV

- Total pilot plant investment: 210,000 EUR
- Man-hours for operation: 3 hours / week

GAC filter with reactivated carbon

Reactivated carbon was used
Virgin fossil carbon: 11-18 tons CO2-equivalents per tons produced
Reactivated carbon: 2-3 tons of CO2-equivalents per tons produced
= Carbon footprint: 6 times lower than virgin fossil carbon

Carbon particle size: 1.7 mm (0.42-2.8)
EBCT wasbetween 34 to 43 minutes



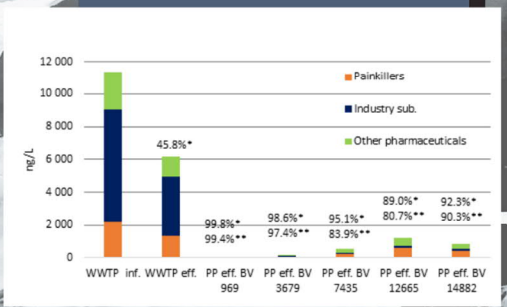
Test period from January 2019 to August 2020
Design flow rate: 30 m3/h (8% of total flow)
Drum filter: 10 µm filtration
GAC: 17 m3
UV design dose: > 40 mJ/cm2, 4 lamps

Total flow amount treated (august 2020): 255,000 m3 or 14,900 BV
Average electricity use: 0.24 kWH/m3
(Microfiltration, pumps, GAC filtration, UV and online measurement)

Most important takeaways

Overall GAC was effective (≥97%) for removal of analysed micropollutants
6 pollutants were breaking through >PNEC after 15,000 BV
Effluent complies with criteria from DK drinking water and EU regulation on water reclamation (microbiology)
Total cost for full scale implementation is estimated to 0.088 EUR/m3
A new follow-up project (Oxytreat) is to reduce breakthroughs and increase GAC durability

Removal efficiency from WWTP influent to pilot plant effluent : 14 critical micropollutants



FOR MORE INFORMATION PLEASE VISIT
www.gfw.pl/projekty/less-is-more/

5. Project outcome summary

The results from the three pilot plants show that it is possible to achieve high removal efficiency of pharmaceuticals and other CECs by introduction of GAC-filtration. Costs are strongly related to exchange of filtration media, either in the form of new or regenerated granules. In order to extend the time between exchanges, pre-treatment is crucial to reduce the content of organic matter. Operation is straightforward and post-treatment with GAC can be readily added following biological treatment and pre-filtration. More findings on GAC:

- The technical feasibility and cost effectiveness have been demonstrated at three different small- and midsized WWTPs during long-term operation in full-scale.
- Project results can facilitate future designs and have shown that GAC-filtration can be installed at a cost of approximately 0.1 €/m^3 including capital and operational expenditures.
- UV-treatment can be added to remove antibiotic resistance and pathogens in order to enable water reuse.
- Environmental performance can be improved using regenerated carbon.

Direct membrane filtration followed by GAC treatment doesn't exhibit the same technology readiness level as GAC for post-treatment. Pre-treatment to DMF, based on coagulation/flocculation and microsieving, shows high potential for energy recovery.

Dissemination has been an important part of the project. The pilot plants have been demonstrated and results successfully communicated to various stakeholders in the South Baltic region. A lot of various communication activities have been used during the project and many different stakeholders have shown a great interest in getting information about the project.

Main dissemination activities has been:

- Polish local events
- National demonstration events
- Various meetings, seminars, conferences and courses where the project was presented
- Audio-visual material about the project and the pilot plants
- Written material in form of newsletters, articles and scientific papers

In all, the LESS IS MORE project has promoted new innovative methods for studies of removal in GAC filters bringing academia and industry closer. It has also contributed to the development of new ideas for future collaboration projects in the field of sustainable water handling in the South Baltic area.