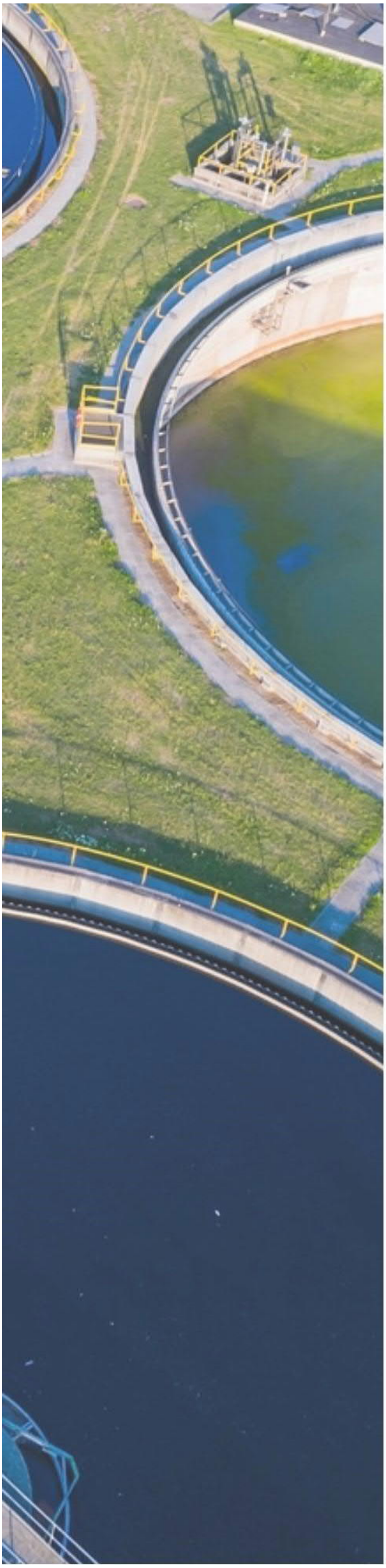

European Regional Development Fund

EUROPEAN UNION

Less is More

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

Deliverable No: 4.2

Enhanced energy reuse

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 was 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 was 30th of June 2021.

The specific project objective was to 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 deliverable presents findings on the energy reuse potential of the direct membrane filtration concept, tested and validated in the pilot-plant placed at Svedala wastewater treatment plant. The potential is compared with the energy demand for wastewater treatment, with and without removal of organic micropollutants.

This report was written by Michael Cimbritz, Åsa Davidsson and Simon Gidstedt.

Lund, June, 2021

TABLE OF CONTENT

Introduction to energy usage and generation in wastewater treatment

To cope with future stricter discharge requirements for municipal wastewater treatment a greater need for resources in the form of electricity and chemicals can be expected. Conventional wastewater treatment is most often based on aerobic biological treatment, i.e. microbial conversion and oxidation of organic matter, which is very energy demanding because of the high need for aeration.

With future requirements at WWTPs, including e.g. higher removal of organic micropollutants, the energy demand can be expected to be even higher. The addition of drum filter, GAC filter and UV disinfection at the LESS IS MORE pilot plant in Slagelse resulted in an increased electricity consumption with 0.24 kWh/m^3 wastewater.

Consequently, more effective methods that allow not only for the wastewater to be treated but also provide opportunities to utilize the resources in the wastewater are of interest. One resource of particular interest is the organic matter, which can be used for the production of renewable energy.

Enhanced energy usage with chemical-mechanical treatment

An innovative compact wastewater treatment concept was tested within LESS IS MORE, in pilot scale at Svedala WWTP, consisting of a chemically enhanced mechanical separation by microsieving (MS) in a drum filter followed by membrane filtration (MF and UF in parallel lines), see Figure 1. This concept is also referred to as the DMF (Direct Membrane Filtration) concept. A detailed description can be found in Deliverable 4.1 – Part I.

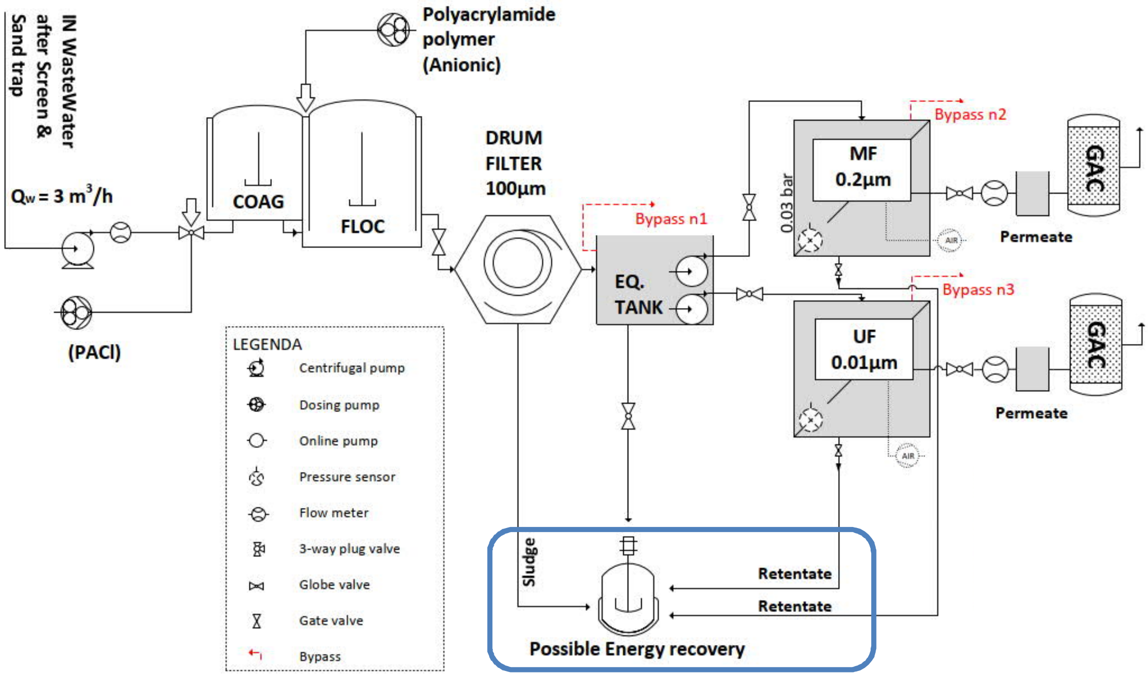

Figure 1. Process scheme for the Svedala pilot plant including chemical-mechanical treatment followed by GAC filtration. Streams for potential energy recovery are indicated with the blue frame.

Removal of organic micropollutants was included with a GAC-filter as a last step, and the evaluation of that part is presented in other LESS IS MORE reports (Deliverable 4.1).

The idea with the tested DMF concept is to replace the primary clarification and activated sludge step, usually found in conventional wastewater treatment plants, with compact separation steps as sieving and membrane filtration. One expected benefit of this concept is increased recovery of organic material from the wastewater by mechanical separation. By the additional use of chemically enhanced primary treatment, the separation efficiency of suspended solids and phosphorus can be further enhanced.

Energy potential and energy demand

Municipal wastewater contains quite a lot of organic matter, but for efficient use of it, removal and thickening to a concentrated sludge is needed. A sludge rich in organic matter can be used as a substrate to produce energy or different kinds of products. In this work, energy production and especially biogas production is in focus since anaerobic digestion is an established sludge treatment method in WWTPs.

The sludge generated by the drum filter (microsieving concentrate) has been evaluated at several occasions with regard to the suitability for anaerobic digestion. Using biochemical methane potential tests, the methane potential of the drum filter sludge was determined. Efficiency of the anaerobic digestion process is highly dependent on the concentration of organic matter in the sludge feed. Therefore thickening is needed and particulate organic matter is an important parameter in evaluating the removal over the separation steps.

With optimized chemical pre-treatment, the majority of the organic content in the wastewater (>95% particulate matter and 87% of the COD) was removed in the drum filter, as MS concentrate in Figure 2. The ultrafiltration membrane retentate, where only about 4% of the organic particles ended up, was much diluted and thereby not an interesting substrate for anaerobic digestion. Therefore, biogas potential of the residual particulate organic matter being removed in the membrane filtration (retentate) was considered less important for the energy balance.

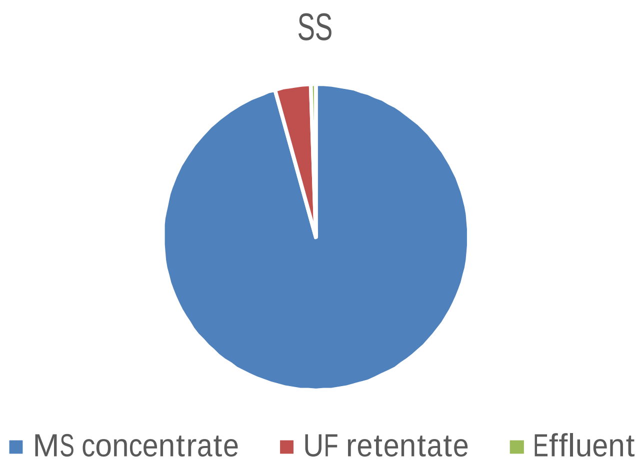

Figure 2. Distribution of suspended solids in the chemically enhanced microsieving (MS) + ultrafiltration (UF) membrane process at the Svedala pilot plant.

Removal of particulate organic matter

The results show, in similarity with other studies, e.g. Vännänen et al. (2016), that a high separation of suspended solids can be achieved by combining chemical and mechanical separation, see Table 2. The high separation achieved with only chemically enhanced primary treatment based on microsieving, i.e. without membrane filtration, is interesting because membrane filtration is the most energy-intensive step in a DMF process. Hey et al. (2018) estimated the energy demand for microfiltration to >50% of the total energy consumption, and the energy demand for chemically enhanced primary treatment to 6%.

Table 1. Abiotic treatment configurations with expected removal of particulate matter

Process configuration	Expected removal
Microsieving (MS)	SS: 50%
Cationic polymer coagulation + MS	SS: 70-90%
Coagulation/flocculation +MS	SS: >95%
Coagulation/flocculation + MS + MF	SS: 100%
Coagulation/flocculation + MS + UF	SS: 100%

Biogas potential of drum filter sludge

Sampling of drum filter sludge and measurement of the biogas potential (Figure 3) were performed at several occasions resulting in an average methane potential of 0.34 Nm^3 CH_4 per kg VS_{in}.

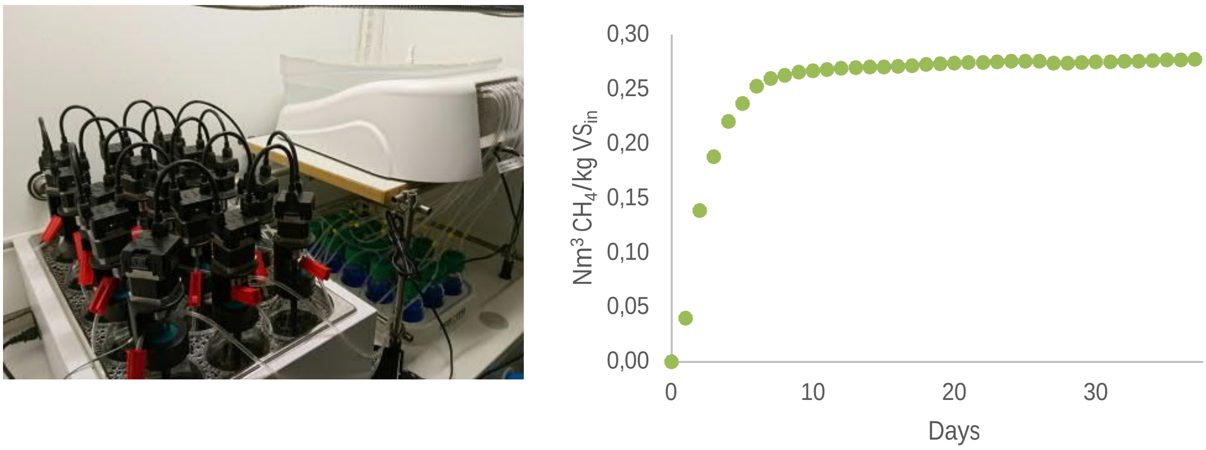

Figure 3. Biogas potential measurements in the AMPTS II (Automatic Methane Potential Test System)

Based on the characteristics of the raw wastewater at Svedala WWTP and the obtained removal of particulate matter during pilot operation of the drum filter, the organic matter removed as volatile solids per treated m^3 of wastewater, 0.26 kg VS/m^3, could be combined with the methane potential to calculate the biogas potential per m^3 wastewater, 0.088 Nm^3 CH_4/m^3. Methane has an energy content of 9.97 kWh per m^3 (Pöschl et al., 2010), so the total energy potential per m^3 wastewater would be 0.88 kWh/m^3 and assuming an electricity production efficiency of 40%, the electricity potential would be 0.35 kWh/m^3.

Energy demand for wastewater treatment

Since full-scale experiences from the DMF-concept are hard to find, the actual energy demand is non-existent. Based on the LESS IS MORE project and experiences from previous pilot-scale operation of a similar concept (Hey et al.,2018), the energy demand of a full-scale wastewater treatment plant including microsieving, microfiltration and conventional sludge treatment (incl. biogas production by anaerobic digestion) was estimated to 0.55 kWh/m^3 treated wastewater. An additional GAC-filtration process would increase that demand. The experiences from the Slagelse pilot, with 0.24 kWh/m^3 for additional treatment through not only GAC, but also pre-treatment (microsieving) and UV-disinfection could be seen as a maximum additional energy demand since microsieving and UV-disinfection are optional.

A comparison with the existing conventional full-scale wastewater treatment at Svedala is in place. The electricity demand per m^3 treated wastewater is 0.7 kWh. This includes biological treatment with extended aeration for nitrogen removal, chemical tertiary treatment and sludge dewatering by centrifugation, but not any GAC-filtration.

Summary of outcomes

The main outcomes from this deliverable are summarized in the Table 2 and in the following points:

- Additional treatment using GAC for removal of organic micropollutants will increase the energy demand at municipal wastewater treatment plants.
- Replacing conventional biological treatment with chemical-mechanical treatment could be a way to reduce the energy demand. In this project, microsieving and membrane filtration were combined into a DMF concept, which was tested and evaluated in pilot-scale.
- Chemically enhanced microsieving could efficiently remove the majority (95%) of the particulate organic matter into a concentrated sludge, whereas only 4% was removed with the membrane retentate.
- Using the microsieve sludge for biogas production would generate a substantial amount of energy which would improve the energy balance of the wastewater treatment plant. Potentially it would be possible to cover 40-60% of the electricity demand by internally produced biogas.

Table 2. Energy potential through biogas production from drum filter sludge and energy treatment demand per m^3 of treated wastewater.

Potential	Per m^3 treated wastewater
Organic matter removed as sludge	0.26 kg VS
Methane potential	0.088 Nm^3 CH_4
Total energy potential	0.88 kWh
Total electricity potential	0.35 kWh

Demand	Per m^3 treated wastewater
WWT incl. MS and MF (Hey et al., 2018)	0.55 kWh
MS, GAC and UV in Slagelse pilot	0.24 kWh
Svedala full-scale without GAC	0.70 kWh

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