WP1-Carbon extraction for energy recovery

D1.1: Optimized design of microscreen and periphery for primary filtration

The project "Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration" (POWERSTEP) has received funding under the European Union HORIZON 2020 – Innovation Actions - Grant agreement° 641661

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Abstract	This report presents key features of the microscreen technology and the experience so far within Veolia on primary treatment. It describes also the further developments pursued within the POWERSTEP project, as well as the design specifications of the two demonstration units in Westewitz (Germany) and Sjölunda (Sweden).

Dissemination level of this document

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Glossary

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
HRAS	High Loaded Activated Sludge
P	Phosphorus
PE	Population Equivalents
SS	Suspended Solids
VWT	Veolia Water Technologies AB
WP	Work Package
WWTPs	Wastewater Treatment Plants

Executive summary

Within POWERSTEP, Work Package 1 addresses the enhanced extraction of organic matter from municipal wastewater in order to increase energy recovery through digestion. Two large-scale units using the Hydrotech (Veolia Water Technologies AB, Sweden) microscreen technology were built and are operated in the wastewater treatment plants (WWTPs) of Westewitz (Germany) and Sjölunda (Sweden).

This report presents key features of the microscreen technology and the experience so far within Veolia on primary treatment. It describes also the further developments pursued within the POWERSTEP project, as well as the design specifications of the two demonstration units in Westewitz and Sjölunda.

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1. Introduction

The European project POWERSTEP aims at developing and demonstrating energy positive WWTPs with the application of innovative processes (Figure 1). POWERSTEP's Work Package 1 (WP1) focuses on enhanced carbon extraction from municipal wastewater as primary sludge. Raw wastewater is treated by physicochemical processes (optional coagulation and flocculation followed by microscreening) for transfer of particulate and partially dissolved organic matter into primary sludge. Along the course of this WP1, microscreen technology will be optimised. The two main objectives are:

- Optimization of two microscreen geometries (drum and disc filter) for maximum carbon extraction into sludge with and without chemical pre-treatment with floc conditioning agents.
- Comparison to other primary treatment options for carbon extractions, including high-load biological processes (e.g. in 2-stage process).

The present report will focus on the review of existing sites featuring microscreens for primary treatment. This review has been used as a building foundation for the design and construction of the two primary treatment units for WWTPs Westewitz (Germany) and WWTP Sjölunda (Sweden)

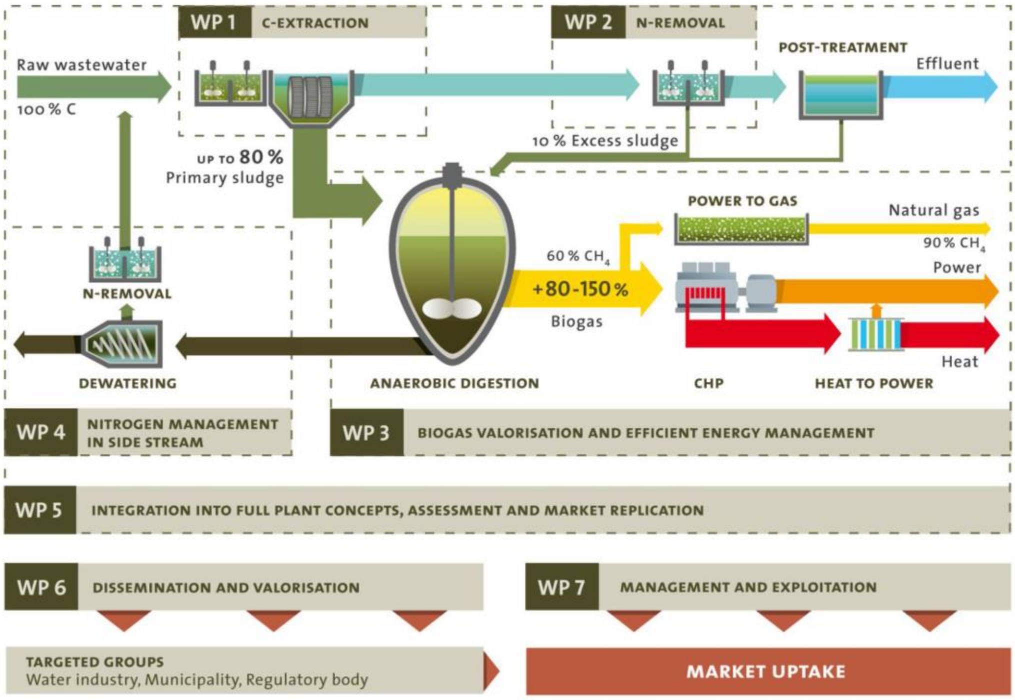

Figure 1: WP1 fit within the POWERSTEP project structure (www.powerstep.eu)

2. What is a microscreen?

Microscreens are gravity-driven and self-cleaning units designed to achieve high performance solid separation with minimal footprint and low energy consumption. In microscreens water flows into a central drum, which supports weaved media mounted in discs (Discfilters) or on custom-made panels mounted directly on the drum (Drumfilters). The treated water, which is filtered by gravity, accumulates in the tank or channel that contains the mentioned drum and leaves the ensemble also by gravity. During filtration, solids are caught on the filter panels, leading to an increase of the filtration resistance and ultimately to an increase of the water level in the central drum. When the water level in the drum reaches a maximum value, the drum starts rotating and high pressure backwashing is initiated with a set of backwash nozzles aligned outside the filtration elements. The backwash water permeating through the filter pores releases the solids retained on the inner side of the filter, which are collected in a tray mounted inside the drum. Filtration is not stopped during backwashing and filtrate can be used as rinsing media. In case of filter overloads, the water that cannot be processed can be by-passed via a set of weirs installed at the filter inlet. These overflows can be either mixed with filtrate or disposed separately.

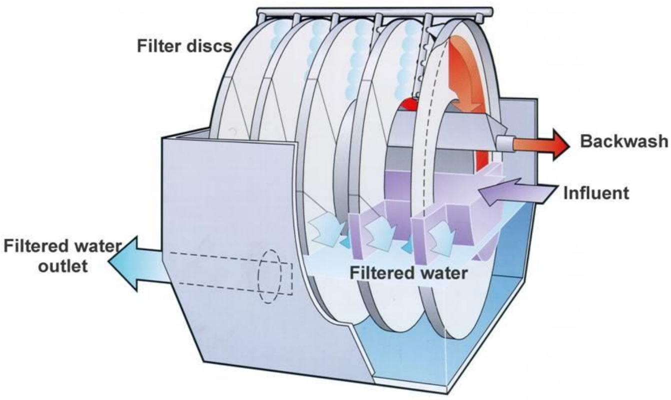

Figure 2: Discfilter working principle

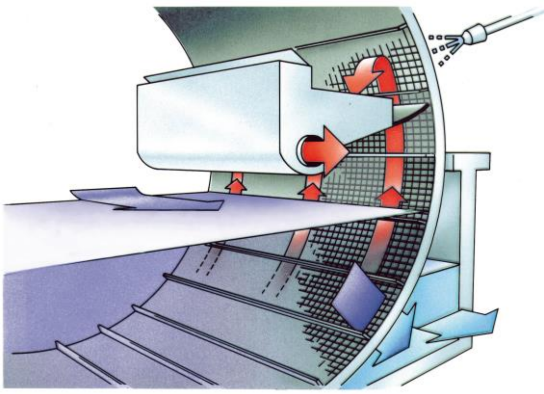

Figure 3: Drumfilter working principle

Microscreens can be delivered self-contained in steel or plastic tanks with an integrated control system and hardware to initiate, maintain and stop the self-cleaning mechanism. Furthermore, packing of filtration media is optimized in order to minimize footprint. These options make drum and discfilters turnkey options for water treatment with minimal construction and operation costs. Energy consumption can range from 5 to 30 Wh/m^3, depending on the type of filtration cloth used (10-1000 µm pores), the type of chemical pre-treatment applied, and the total suspended solids (TSS) loading pattern (Kängsepp et al., 2016; Remy et al., 2014).

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3. Primary Treatment with microscreens

TSS in wastewater can be the source of many environmental and health-related problems in the receiving water bodies. Early removal of these pollutants can decrease the load of certain pollutants such as Chemical Oxygen Demand (COD) on subsequent treatment stages and hence contribute to the minimization of the footprint and resource use (e.g. oxygen or energy) in subsequent treatment steps (Siegrist, 2008). Primary treatment is often performed in rectangular or circular sedimentation basins where the wastewater particles are allowed to settle at overflow rates of 1-2 $m^3/m^2/h$ (Metcalf & Eddy Inc et al., 2002), taking the tank footprint area as reference.

Microscreens (Drum or Discfilters) allow loading rates 10-20 times higher than in clarifiers and still achieve similar or even greater TSS removals. As the area in a microscreen is optimally packed within the footprint of the equipment, the space required for installation can be substantially reduced.

Coagulants and flocculants can be added upstream the microscreens in order to improve the filterability of the particles, precipitate dissolved Phosphorus (P) and enhance the TSS and COD removal efficiencies. Hydraulic retention times are minimized to a few minutes and wastewater flow is kept turbulent, allowing for real-time process control, lower greenhouse gas emissions, and maximization of the energy recovery from the organic carbon present in the wastewater, while minimizing the chemical dose required.

3.1. Review of microscreen use in primary treatment

Extensive testing (Table 1) has been performed by Veolia Water Technologies AB (VWT) at several different municipal WWTPs in Sweden (Malmö, Helsingborg, Stockholm and Lund), Denmark (Hillerød and Copenhagen), and Germany (Berlin). Recently, pilot studies were also completed in USA (Florida). Several of the tests have been performed on a long-term basis providing operational experience with or without chemical pre-treatment and using both Drum- as well as Discfilters.

Piloting results demonstrate that both filter types are viable options for primary treatment of municipal wastewater, with minimal footprint, and the tests have been important in order to create sound design data and for establishing the technology in full-scale in municipal WWTPs (for full-scale references see Table 2).

Table 1: Pilot tests performed by VWT

Site name	Pre-treatment tested			Microscreen used
	No chemicals	Flocculation	Coagulation and flocculation	
Sjölunda WWTP (Malmö, Sweden)	X	X	X	Drumfilter and Discfilter
Öresundsverket WWTP (Helsingborg, Sweden)	X	X	X	Discfilter
Källby WWTP (Lund, Sweden)	X	X	X	Discfilter

Lynetten WWTP (Copenhagen, Denmark)	X	X	X	Drumfilter
Hillerød WWTP (Denmark)	X			Drumfilter
Florida (USA)	X			Discfilter
Stahnsdorf WWTP (Berlin, Germany)			X	Drumfilter

Table 2: VWT's Full-scale installations of disc and drumfilters for primary treatment

	Site	Start-up year	Filter type	Pore size (μm)
Without chemical pre-treatment	Bångbro (Kopparberg, Sweden)	2003	2 Drumfilters	150
	Langnes (Tromsø, Norway)	2005	2 Drumfilters	100
	Agniéres en Devoluy (France)	2011	1 Discfilter	40
	Stavanger (Norway)	2017	20 Drumfilters	100
	Odderøja (Norway)	2017	12 Drumfilters	100
With chemical pre-treatment	Näs (Sweden)	2010	1 Drumfilter	80
	Westewitz (Germany)	2016	1 Drumfilter	40
	Recreational Park (Canada)	2016	1 Drumfilter	100

3.1.1. Primary filtration without chemical pre-treatment

As mentioned above, microscreens can be used as a compact and cost-effective solution for primary treatment of municipal wastewater, i.e. as an alternative to conventional primary clarification. It is recommended that the equipment is preceded by screening followed by grit and grease removal. Without chemical addition, removal rates of about 50% of the TSS (equivalent to the removal efficiency obtained in primary clarifiers) are attainable. This percentage typically corresponds to 20-30% in BOD-removal. Below follow some examples from existing full-scale installations.

Agniéres en Devoluy WWTP, France

The microscreen in Agniéres en Devoluy (southern France, installed in 2011) is the first VWT reference with direct primary filtration based on disc filtration (no chemical pre-treatment). The Discfilter (equipped with 40 μm media) was designed for 150 m^3/h and was built upstream of an AnoxKaldnes MBBR, and it is only used when the plant is highly loaded during holiday season. Since start-up, the Discfilter has consistently demonstrat-

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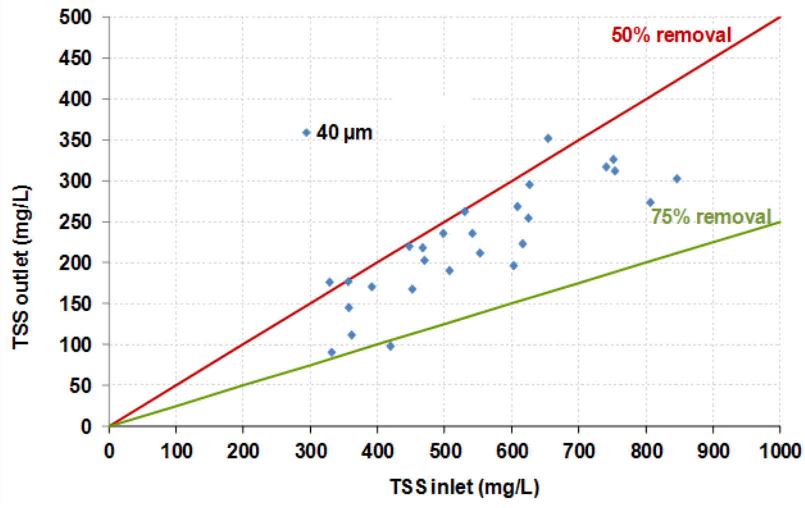
ed TSS removals over 50%, removal of total P between 5 and 20% and a removal of total COD between 30 and 50% (Figure 4).



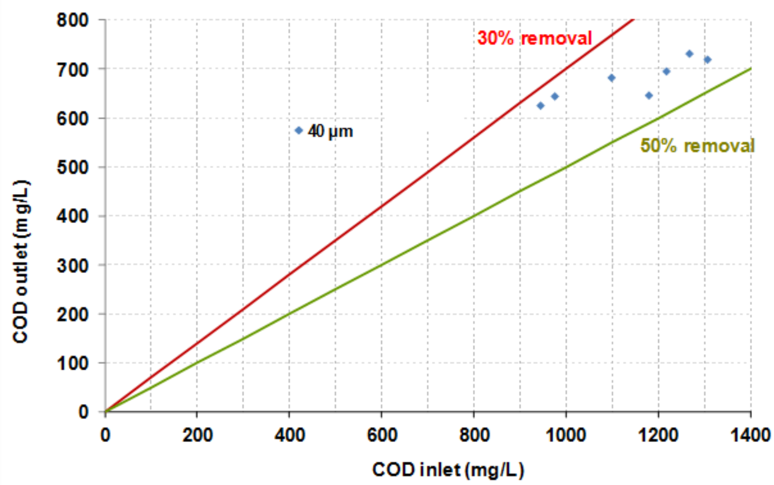


Figure 4: TSS and COD removals in Agnieres en Devoluy's microscreen

Bångbro WWTP, Sweden

Bångbro WWTP (Kopparberg, 40,000 PE, 2004) was upgraded with primary treatment in order to reduce loading on the existing biological treatment. Two Drumfilters could be installed indoors without extending the area of the plant, while reducing the loading significantly. Commissioning studies revealed that the TSS removal was similar with 60 and 150 µm pore size (Figure 4). Hence, in order to optimize the hydraulic throughputs, a 150 µm filtration cloth was installed. Removal efficiency depended on the weather conditions – rain events were associated with lower TSS concentrations and lower TSS removals, probably due to a higher content of finer material in the TSS (clay and silt rinsed by the rain). Chemical pre-treatment or smaller pore sizes are therefore required to sustain TSS removals.

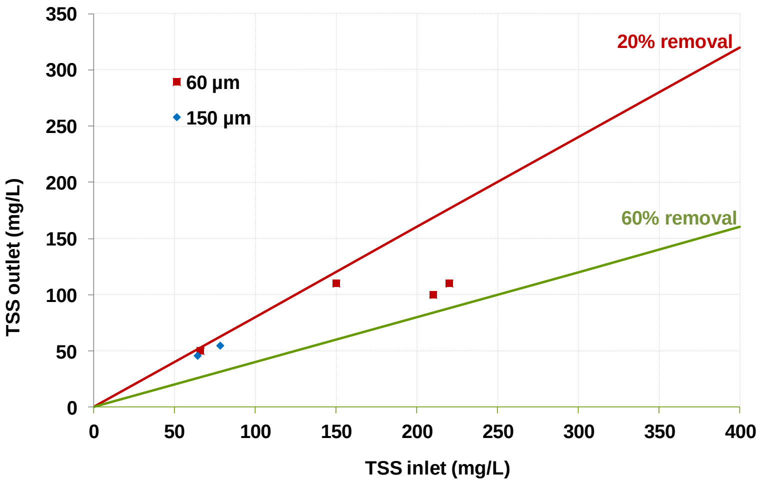


Figure 5: TSS removals in Bångbro's microscreen

Langnes WWTP, Norway

The primary treatment plant in Tromsö, sized for 1200 m³/h, is equipped with two Drumfilters (100 µm panels) to enhance the operational flexibility of the site, allowing for maintenance operations in periods of low TSS loading. The filters can achieve the Norwegian requirements for primary treatment (average 50% TSS removal, and average 20% BOD removal, Figure 6).

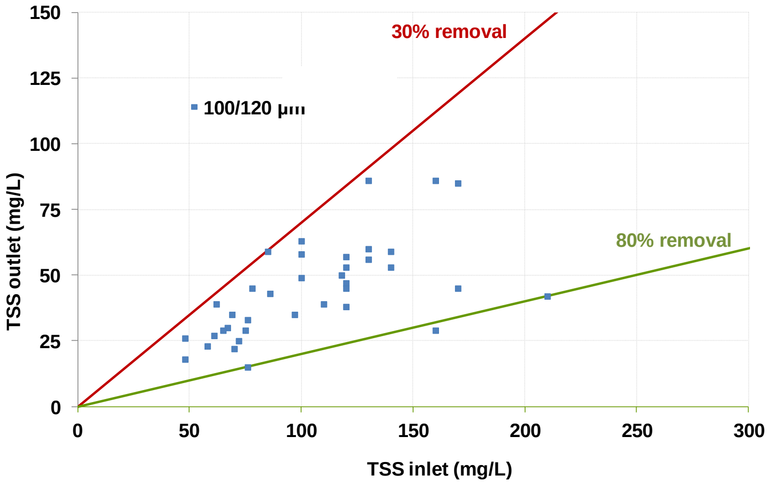


Figure 6: TSS removal in Langnes' microscreens

Other piloting experiences

Research and operational efforts in Southeastern USA (Discfilter) and Denmark (Drumfilter), have proven that the pore size of the filters (60, 80, 100, 200, 300, 500, and 800 µm) can be adjusted to target specific removal efficiencies in primary filtration applications (Figure 7 and Figure 8).

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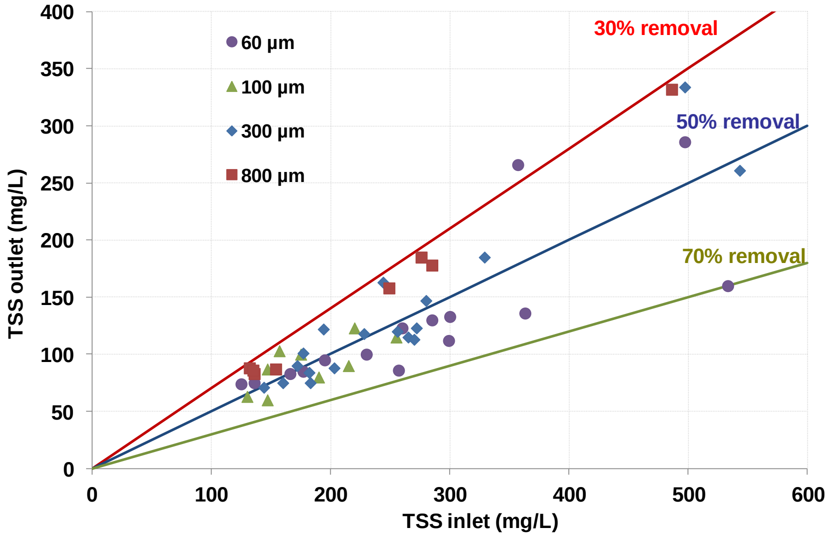

Figure 7: TSS removals with Drumfilter during pilot test at the Hillerød WWTP (Denmark)

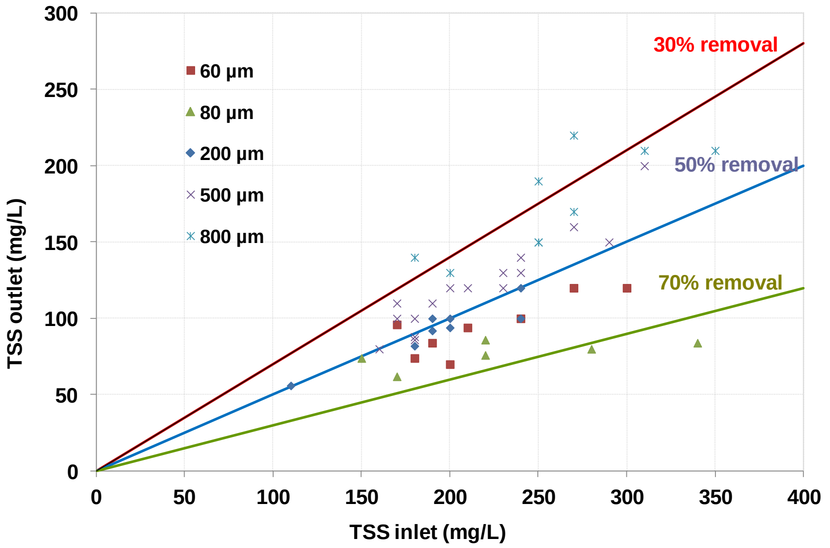

Figure 8: TSS removals with Discfilter during pilot test in Florida (USA)

3.1.2. Primary filtration with flocculation upstream

TSS removals can be enhanced by adding polymer in a flocculation stage upstream of the microscreen. With a correctly designed flocculation process, TSS removal in the order of 70-90% can be achieved without increasing the sludge production (no chemical sludge is formed). The reduction of particulate organic fractions will follow accordingly. Additionally, this configuration allows for dissolved fractions of phosphorus to remain in the water, which could be of interest in certain applications.

Polymer addition for enhanced TSS-removal was successfully tested in pilot trials with Drum- and Discfilters at Sjölunda WWTP (Malmö, Sweden). The TSS reduction with polymer addition and a 40 µm filtration cloth was between 80 and 99% (compared to 40 and 70% without chemical pre-treatment) (Figure 9). The Drum and Discfilter resulted in similar removal efficiencies, but the discfilter required a smaller footprint.

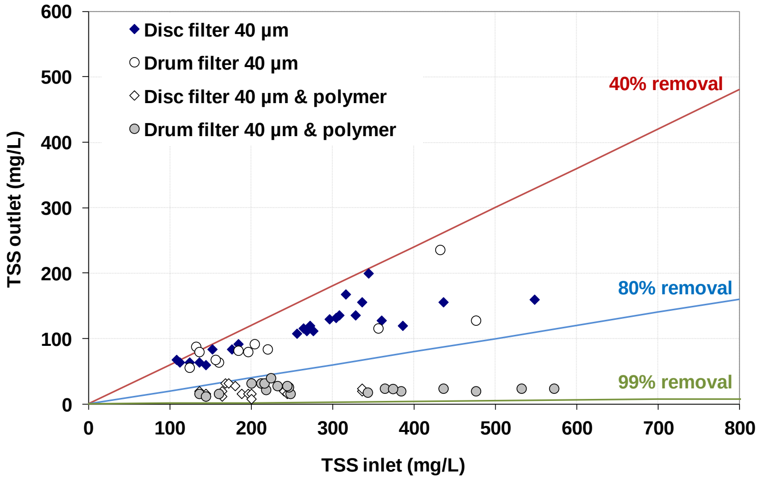

Figure 9: TSS removals in pilot test with flocculation upstream Disc and Drumfilter in Sjölunda (Sweden)

3.1.3. Primary filtration with coagulation and flocculation upstream

It is possible to consider a microscreen for a phosphorous pre-precipitation process. With a properly-designed coagulation and flocculation step more than 90% reduction of TSS and total P can be expected. A 2-stage chemical pre-treatment with coagulant and polymer dosing for enhanced TSS removal was successfully tested in pilot trials in Denmark, Sweden and Germany. The first full scale installation was located in Sweden.

Pilot tests with coagulation, flocculation, and microscreens at Sjölunda WWTP in Malmö

Drum filtration with preceding coagulation/flocculation was evaluated in a one-year pilot test at the Sjölunda WWTP. COD-removal was in average 70% and TSS removal higher than 90%. P-removal was a direct function of $FeCl_3$-dosing. Typical removal efficiencies can be observed in Table 3. Detailed findings of this study are further described in Ljunggren et al., 2007.

Table 3: Typical influent and effluent concentrations achieved in pilot study with coagulation, flocculation, and filtration performed at the Sjölunda WWTP

Parameter (mg/L)	TSS	TP	TPsoluble	COD	CODsoluble
Influent	284±130	7.4±2.6	3.8±1.3	672±307	230±72
Effluent	16±11	1.8±0.8	1.3±0.7	206±79	179±57

Pilot with Discfilter at Öresundsverket WWTP, Sweden

Recent pilot testing at Öresundsverket WWTP in Helsingborg, with optimized coagulation/flocculation and disc filtration of raw wastewater, showed the possibility to achieve <0.3 mg Tot-P/L and <10 mg TSS/L with inlet concentration of 7 mg Total-P/L and 200 mg TSS/L.

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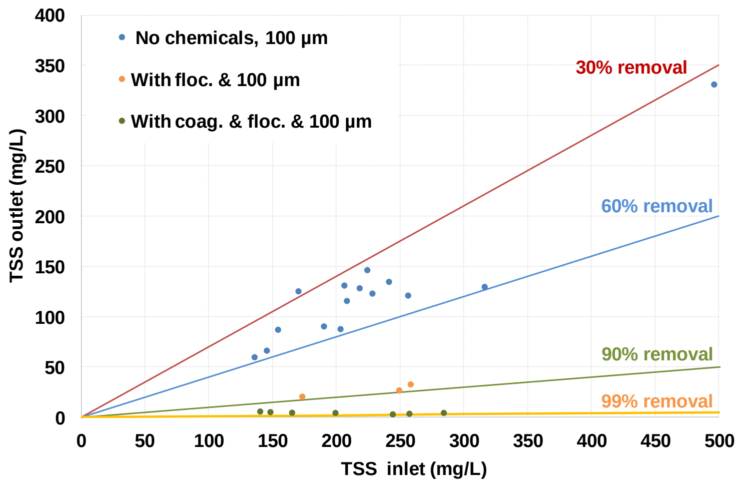

Figure 10: TSS removals in pilot test with coagulation and flocculation upstream Discfilter in Öresundsverket WWTP (Helsinborg, Sweden)

Pilot with Drumfilter at Knislinge WWTP, Sweden

VWT, Lund University (LTH) and other water companies in Sweden (ConPura AB, Kemira, VA SYD and NSVA and Östra Göinge municipality) partnered for process development aiming to upgrading small and medium sized WWTPs. The developed concept included three units: Conpura's compact pre-treatment plant ConPact B (containing screening, an aerated grit chamber and grease removal), coagulation and flocculation tanks and a Hydrotech Drumfilter. The plant allowed a modular approach that could be easily extended if necessary. The investment cost was estimated to be significantly less than the cost of building a conventional treatment plant. Controlled carbon removal (as BOD) could be achieved with careful adjustment of the chemical dose upstream the microscreen (Figure 11).

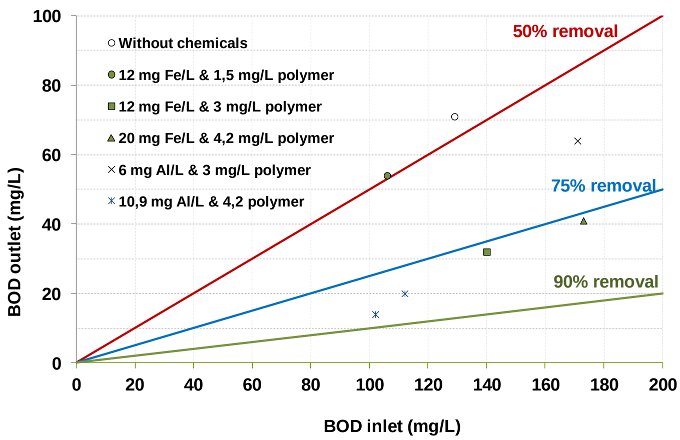

Figure 11: BOD removals in pilot test with coagulation and flocculation upstream Drumfilter in Knislinge WWTP (Sweden)

Drumfilters for COD harvesting

The possibility of using drum filtration for primary wastewater treatment in order to maximize the energy recovery in wastewater treatment plants without compromising the need for nutrients in the biological treatment steps downstream (denitrification and P removal) was studied within AVERA project, funded by the Foundation for Development of Technology in the Danish Water Sector (VTU Fonden). The AVERA project was managed by Krüger A/S, and the test were conducted at Lynetten WWTP in Copenhagen. The project demonstrated that controlled TSS removal was feasible with different chemical pre-treatment strategies and a 100 µm screen (Figure 12).

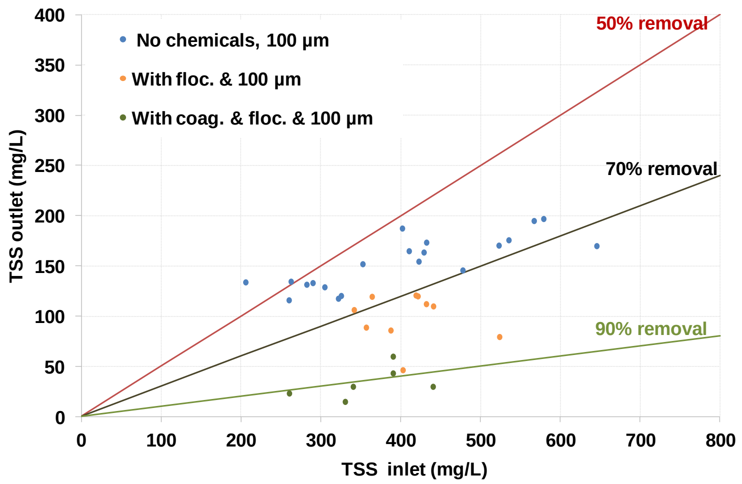

Figure 12: TSS removals achieved with different chemical pre-treatment strategies during the AVERA project (Lynetten WWTP, Copenhagen, Denmark)

The same concept was evaluated at Stahnsdorf WWTP (Berlin) within the CARISMO (CARbon IS MOney) project, which was managed by the Berlin Center of Competence for Water and funded by Veolia Water and Berliner Wasserbetriebe. It was demonstrated that chemically enhanced microscreening with coagulation and flocculation upstream allowed consistent TSS removals above 90% and the production of more biogas in the digestion process, thus making the WWTP closer to becoming energy producing (Remy et al., 2014). The CARISMO project was nominated to German Sustainability Award 2014 (Figure 13).

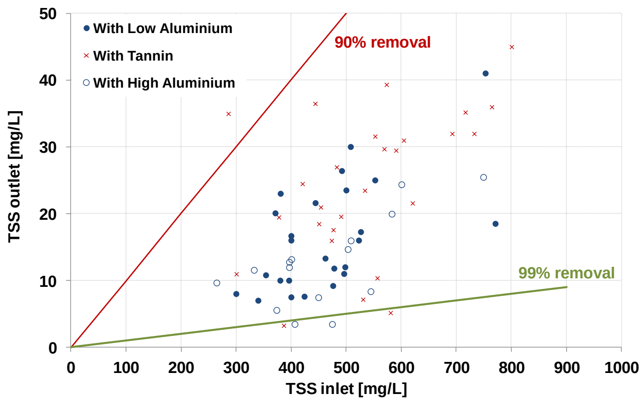

Figure 13: TSS removal achieved with coagulation, flocculation, and drum filtration during the CARISMO project (Stahnsdorf WWTP, Berlin, Germany)

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Full scale installation in Näs WWTP (Avesta, Sweden)

Treatment based on coagulation/flocculation followed by microscreening can be used without subsequent biological treatment to reach European treatment standards. In the Avesta WWTP (central Sweden, 600 PE, 2010) the process, including screens and aerated grit chamber, is successfully applied in order to achieve <0.5 mg Tot-P/L. With optimized coagulation/flocculation the TSS and BOD (or COD) removal often exceeds 70% (Figure 14).

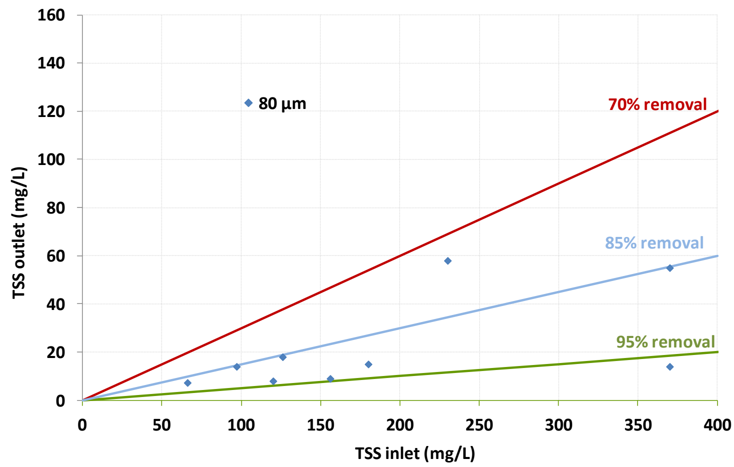

Figure 14: TSS removals achieved with coagulation, flocculation, and Drumfiltration in the Näs WWTP (Avesta, Sweden)

3.2. Large-scale demonstration units of POWERSTEP in Westewitz and Sjölunda WWTPs

In the POWERSTEP project, two large scale microscreen units will be operated at WWTPs Westewitz (Germany) and Sjölunda (Sweden), with the purpose to maximise the COD extraction as a first stage in an energy efficient WWTP treatment schemes.

Beyond the purposes of the trials "enhanced COD extraction", the specific objectives of the trials will be:

- Westewitz WWTP: demonstrate a new panel geometry and a new backwash regime to decrease the volume of backwash water and increase the concentration of suspended solids towards "digestion ready" sludge (SS > 4%)
- Sjölunda WWTP: demonstrate at large scale disc filter in combination with chemical pre-treatment

4. Design of primary treatment plant in Westewitz WWTP

4.1. Site description

The Westewitz WWTP was started-up in 2009 and treats the wastewater from 2,000 inhabitants in Saxony (Germany), collected from the separated gravity sewer system. The plant has COD (<70 mg/L), BOD_5 (<25 mg/L), TP (<8 mg-P/L), and TN (<18 mg-N/L) effluent requirements in spot samples. The wastewater is pumped at the inlet of the plant to a combined pre-treatment (6 mm screening and grit trap) before it is pumped further to the biological stage, which consists of two Sequencing Batch Reactors (SBRs, Figure 15). Following the SBRs, the biological excess sludge is pumped to a sludge storage tank where the supernatant is pumped backed to the SBR feeding pumping station. The thickened excess sludge is transported to another WWTP of the region to be dewatered and disposed.

The overreaching goal in Case Study 1 is to demonstrate that primary treatment with a microscreen and proper process control of the biological treatment step can enable WWTPs to become energy positive. In order to test the concept, a microscreen will be installed in the Westewitz WWTP. One of the SBRs will be fed directly with primary water. The other SBR (POWERSTEP SBR) will be fed with filtrate from the microscreen. Energy use and methane generation potential from the generated sludges will be recorded regularly in order to demonstrate the concept.

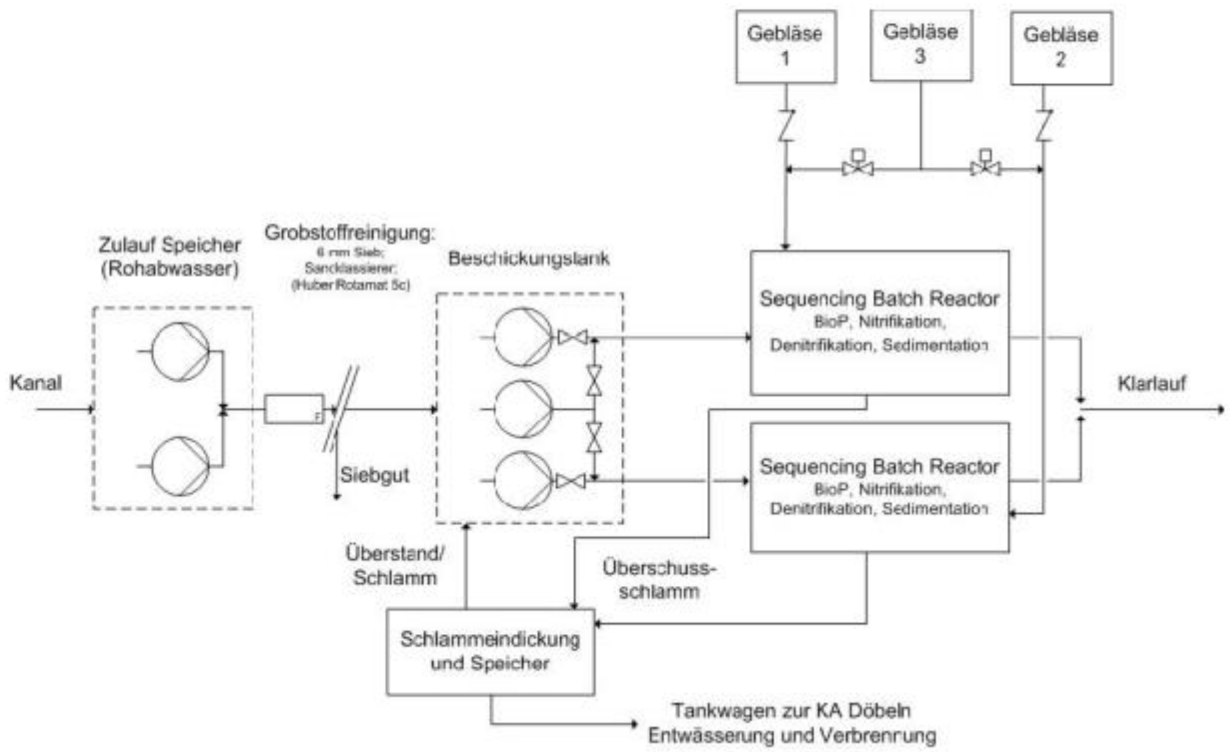

Figure 15: Westewitz WWTP diagram

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4.2. Influent characteristics

In order to design the filtration unit, KWB analysed historical flow data in Westewitz for the years 2011-2015 in 1 hour time step (Figure 16). The mean value laid by about 10 m^3/h, and the 99% percentile value was about 30 m^3/h. It was therefore decided to design the filter with a peak flow capacity of 30 m^3/h without use of chemical, providing a safety factor of about 50% when working with chemical addition.

Figure 16: Historical hourly flow repartition at WWTP Westewitz (2011-2015)

Analytical data gathered from the site between January 2011 and August 2015 was analysed and summarized in Table 4 and completed with analyses performed in 2016 during the POWERSTEP trials. Comparison of the average composition of the wastewater to values in the literature revealed that the Westewitz wastewater has high strength (Henze et al., 2002; Metcalf & Eddy Inc et al., 2002) and has a high potential for carbon extraction (about 70%).

Table 4: Analytical influent data from the Westewitz WWTP collected between 01/2011 and 08/2015 and in POWRSTEP trials

	Operational data 2011-15	POWERSTEP Characterization
TSS average (mg/L)	n.a.	308
COD average (mg/L)	825	681
COD 95%-ile (mg/L)	1229	-
CODs average (mg/L)	n.a.	211
BOD average (mg/L)	482	211
BOD 95%-ile (mg/L)	722	
TN average (mg-N/L)	49.1	82
TN 95%-ile (mg-N/L)	72.9	
N-NH_4 (mg-N/L)		37
TP average (mg-P/L)	12.5	9.3
TP 95%-ile (mg-P/L)	17.9	
PO_4-P (mg-P/L)	n.a.	4.4

4.3. Lab characterization studies

The Berlin Centre of Competence for Water (KWB) performed jar tests with the raw wastewater from the Westewitz WWTP in order to determine the appropriate chemicals and concentrations for pilot plant operation, and the influence of the mesh size for the micro-screen. 125 jar tests were performed testing 7 different polymers from 2 suppliers, with and without 2 different metal salts as coagulant. Effective performances for COD extraction were obtained with the polymer H6456 of the company Hydrex in the range 4-8 g polymer/kg-TSS = 1.2-2.5 mg/L considering the average TS value of 0.32 g/L (Figure 17) and the coagulant VTA59 in the range 7.5 – 15 g-Al/kg-TSS, typically added proportionally to the polymer dose. Up to 75% COD removal could be achieved, with a correlation between specific dose and performance in the considered dosing range, which should enable control command based on COD extraction rate if required by the denitrification performance of the downstream SBR unit. Based on the jar tests, a mesh size of 40µm was selected to start the demonstration trials in Westewitz.

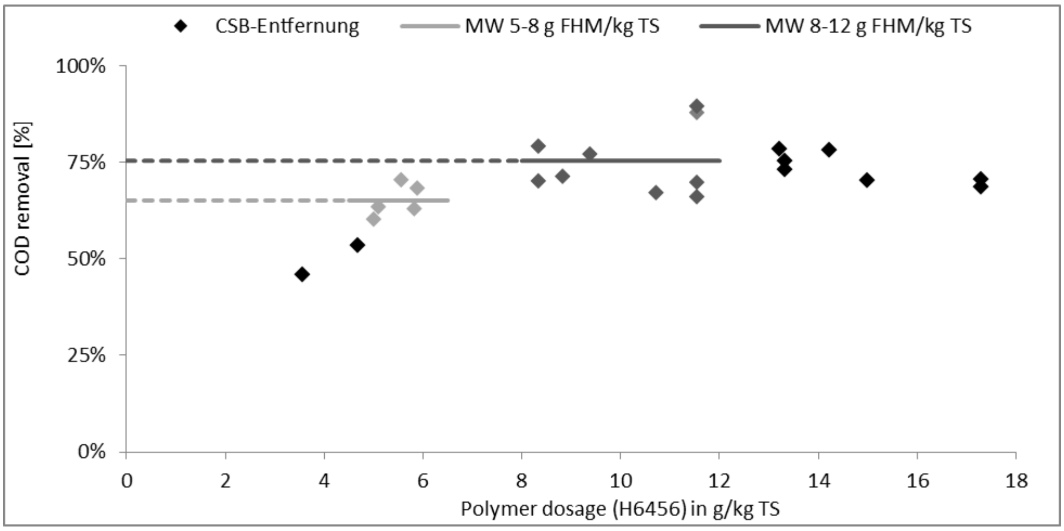

Figure 17: COD removal compared versus different polymer dosage concentrations

4.4. POWERSTEP plant design in CS1

The plant was designed and constructed during 2015-2016, and installed and commissioned in Oct-Nov 2016. The plant specifications were provided to VWT by KWB, given the requests of the wastewater treatment plant operator (OEWA) and the German Water Authority. The microscreen and all ancillary equipment were divided in two containers, designed to be piled against each other. The main idea behind this layout was to ensure gravity flow from the filtration unit (placed in the elevated container) into the POWERSTEP SBR and the sludge storage tank while using the hydraulic head available after the pumping station present on site after pre-treatment. The elevated container can be accessed through a set of stairs and a platform mounted in front of the unit (Figure 18).

Based on the experience from previous pilot studies and full-scale installations (Chapter 3) as well as the jar tests performed by KWB, VWT recommended a microscreen design with 40 µm in order to guarantee performances equivalent to those obtained in primary

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clarifiers without the need of chemical pre-treatment. In later stages of the project, where chemicals will be used for flocculation and later COD extraction, more open weaves can be considered in order to maximize the hydraulic throughput through the microscreen unit – 100 or even 300 µm are recommended given the pilot experiences compiled in this report. The designed plant is expected to have a peak flow capacity of 30 m³/h.

Figure 18: POWERSTEP microscreen plant in the Westewitz WWTP with SBR reactor

4.4.1. Filter container

The filter container (the one with the higher elevation, Figure 19), features coagulation and flocculation tanks upstream the microscreen. Both tanks were sized after VWT's guidelines. Both coagulant and flocculant are injected into the liquid stream in order to ensure full dispersion and highest effectivity. Top mounted mixers ensure effective particle contact during the wastewater residence time in both tanks. Coagulation and flocculation tanks are covered and the air phase can be continuously extracted to the atmosphere by a fan installed in the container wall.

Figure 19: The filter container at Westewitz WWTP, with coagulation tank, flocculation tank, drum filter and control cabinets.

The Drumfilter selected for CS1, will ensure robust particle retention even with the existing 6 mm pre-treatment screen. The filter is automatically backwashed on demand by the installed flushing pump, according to the standard Hydrotech control philosophy. One redundant pump was added to the filter design in order to ease maintenance and ensure continuous operation of the microscreen. Filtrate is used as backwashing media, and a self-cleaning strainer installed in the backwash line protects the backwash nozzles from being blocked by particles present in the filtrate. The backwash line is equipped with a flow meter and a pressure transducer to alert the operator of blockages and malfunctions in the filter cleaning system. A valve can be used to in order to change the backwash operating pressure (Figure 20).

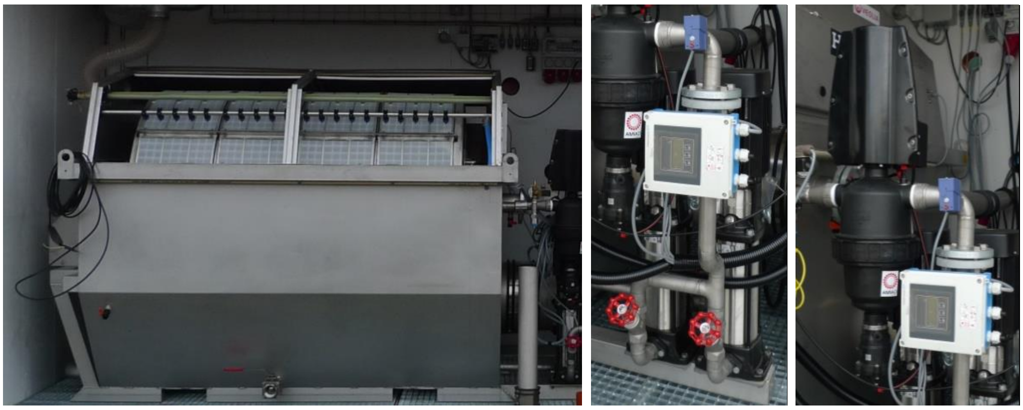

Figure 20: Filter unit and ancillary equipment in the backwash line

The filter features two additional cleaning modes designed to wash the filter in case of clogging. The high-pressure backwash will be used when clogging is first detected by the operator. A set of nozzles will then spray water at 80 bars in order to slough biofilm and other sticky fouling agents blocking the pores of the weave. Secondly, additional automatic chemical cleaning can be considered under acidic or caustic conditions in order to ensure complete removal of mineral precipitates or biofoulants. The filter unit is also covered, and the air phase is connected to the ventilation system earlier mentioned.

Water flows by gravity through the whole treatment train. Effluent and sludge are led by plastic pipes into the POWERSTEP SBR and a sludge tank, respectively (Figure 21). The sludge storage tank also collects the SBR excess sludge. A set of sampling valves are installed throughout the plant to ensure safe offline monitoring of the filter influent, effluent, and sludge. The turbidity in the influent, effluent from the flocculation tank, and filtrate are continuously monitored by a set of turbidity probes connected to the control system of the plant.

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Figure 21: Sludge storage tank and piping connections at the Westewitz WWTP

4.4.2. Chemical container

All chemicals, dosing, and cleaning equipment are stored in the lower container of the assemble, in order to maximize the space in the filter container. Being at ground level also facilitates the loading and unloading of chemicals. Coagulant (dosed into the coagulation tank) will be used at the plant for P removal and as flocculating agent for colloidal COD. Acetate (dosed in the filtrate pipe) will be used as external carbon source in case the POWERSTEP SBR runs into carbon limitations during the test phase. Both chemicals are stored in IBC tanks placed on top of spill basins (Figure 22) and are dosed into the system by diaphragm pumps.

Figure 22: The chemical container in the middle of the construction work

The chosen polymer station (Figure 23) can be used to automatically prepare stock solutions of polymer product from both powder and liquid polymers. Stock solutions are matured with gentle mixing, stored, and pumped on demand into the flocculation tank by a dosing diaphragm pump.

Figure 23: Polymer station

The so-called chemical container also contains a water buffer tank in order to ensure a reliable supply of pressurized water to the plant. Cleaning chemicals are also stored in this container together with the compressor for the high pressure cleaner, and magnetic pumps to feed the automatic chemical cleaning system with caustic and acidic cleaning agents, if needed.

4.4.3. Control cabinets and power boxes

The plant can be controlled both through the provided control cabinets in the filtercontainer (

Figure 24) or through the WWTP central control software via the programmed communication protocol between the VWT containers and the WWTP's control system. Turbidity in influent, effluent from the flocculation tank, and filtrate, treated flows, backwash times, dosing rates, sludge production, energy, and water consumption will be logged for further data analysis.

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Figure 24: Manual control panel in the microscreen plant at the Westewitz WWTP

4.5. Novelty in POWERSTEP introduced in CS1

The presented POWERSTEP case study will introduce the following innovations within the use of microscreens in primary treatment:

- Use of filtrate for backwashing filter media, leading to a reduction of the operation costs and the possibility of using the technology in areas with water scarcity.
- Digestion ready sludge (4-6% TS) will be targeted through the use of lower backwashing pressures, the introduction of new nozzle types, and the use of a new Drumfilter panel support that minimizes the amount of water lifted by the drum into the sludge trough.
- CS1 will be the first operating reference in primary treatment with the new Alphaflex Drumfilter panels. This VWT patented technology maximizes the effective filtration area while keeping the mechanical strength of the previous Drumfilter panel. Furthermore, the optimized design, with an angled plastic support matrix, facilitates the transport of heavy particles into the sludge trough leading to a less stringent pre-treatment need upstream the microscreen.
- Automatic chemical cleaning and high pressure cleaning systems will be applied for the first time in order to minimize the effect of fat, oil, grease, biofoulants or other mineral precipitates in the hydraulic performance of the unit. This will be the first VWT primary reference without fat oil and grease removal upstream.

5. Design of primary treatment plant in Sjölunda

5.1. Site description

The Sjölunda WWTP started up in 1963 and serves 300,000 inhabitants from the south of Sweden (Malmö, Burlöv, Lomma, Staffanstorp, and Svedala). The wastewater is led into the plant by several pumping stations located downstream each catchment area. The plant has BOD_7 (<12 mg/L), TP (<0.3 mg-P/L), and TN (<10 mg-N/L) requirements, all of them to be measured as monthly average. The main challenges for the future of the WWTP are the steep increase in population of the Malmö area and more stringent regulations.

The main treatment (Figure 25) line features primary treatment with 3 mm screens, grit removal, and primary clarifiers. Coagulant is added in the grit chamber for P pre-precipitation. The biological treatment consists of four High Loaded Activated Sludge reactors.

(HRAS) systems followed by trickling filters and post-denitrification moving-bed biofilm reactors for complete N removal (refer to D2.2 for details). Tertiary solids are removed by flotation. Additional coagulant can be added into the dissolved air flotation units if required.

The main goal of the Sjölunda Case Study is to prove that stable N removal is achievable via a 3-stage concept with COD removal, nitritation and anammox in main stream. Initially, COD will be removed in the primary clarifiers and HRAS existing at the Sjölunda WWTP. The resulting wastewater (low in C, high in N) will flow into autotrophic biofilm reactors for subsequent N removal. In a later phase, a Discfilter with coagulation and flocculation will replace the primary clarifiers and HRAS stage, aiming to achieve the same effluent characteristics as during the initial phase (refer to D2.2 for details).

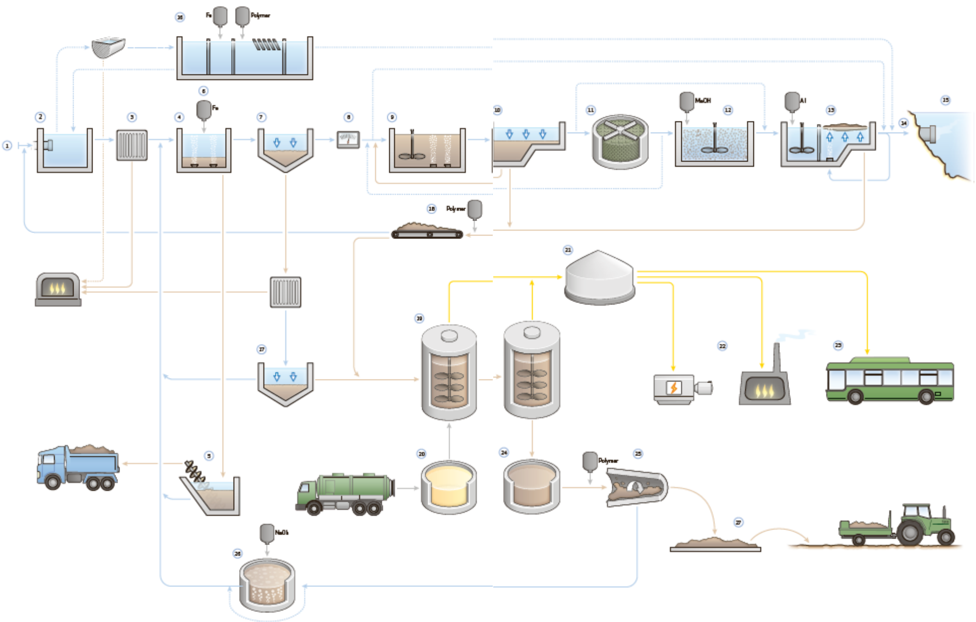

Figure 25: Wastewater treatment train in the Sjölunda WWTP

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5.2. Primary wastewater characterization

Table 5 shows the variations in primary wastewater quality and removals in the existing COD removal stage (primary clarifier and HRAS) during the period August 2015-August 2016. The water at the Sjölunda WWTP fits within the range of what is considered medium strength municipal wastewater (Henze et al., 2002; Metcalf & Eddy Inc et al., 2002).

Table 5: Primary wastewater characterization and performance of HRAS plant in the Sjölunda WWTP

	Influent Primary Treatment	Effluent Activated Sludge	Removal (%)
TSS average (mg/L)	242	11	96
TSS 95%-ile (mg/L)	420	20	95
COD average (mg/L)	515	52	90
COD 95%-ile (mg/L)	810	68	92
BOD average (mg/L)	240	11	95
BOD 95%-ile (mg/L)	347	15	96
TN average (mg-N/L)	45	31	31
TN 95%-ile (mg-N/L)	57	46	20
TP average (mg-P/L)	5	0,6	88
TP 95%-ile (mg-P/L)	7	1,0	86

5.3. Lab characterization studies

The primary wastewater at Sjölunda WWTP was sampled by VWT in July and August 2015 and subjected to particle size analyses. TSS concentrations were found to vary considerably, being in a range of 106 -647 mg TSS/L. All samples were collected at dry weather, and hence storm water dilution or first flush phenomena do not seem to explain these large variations. However, the particle fractionation of the TSS varied with the TSS concentration - the two denser waters appeared to have a larger fraction of larger particles, with about 50% of the TSS mass larger than 100 µm (

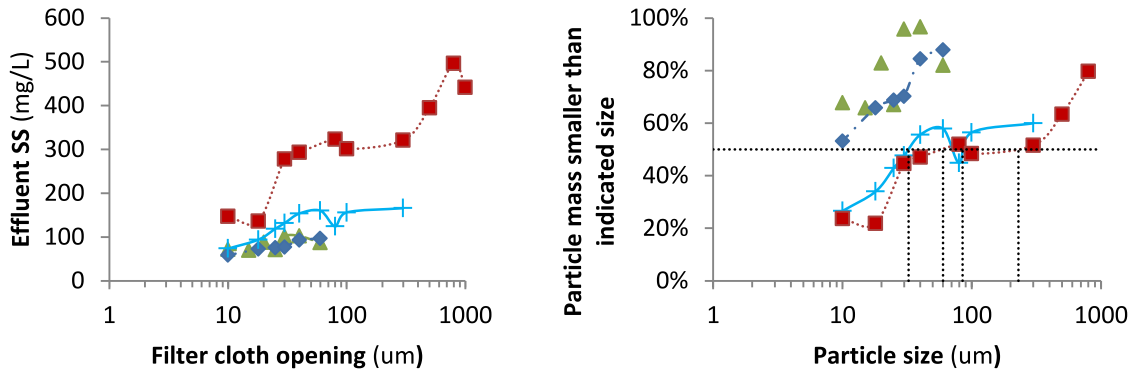

Figure 26). Concurrently, in the waters less concentrated in TSS (≈ 100 mg/L), more than 50% of the particles appeared to be smaller than 10 µm, which is the smallest standard filter cloth opening available in a microscreen (

20150731 Influent SS = 106 mg/L
20150820 Influent SS = 227 mg/L
20150813 Influent SS = 101 mg/L
20150828 Influent SS = 647 mg/L

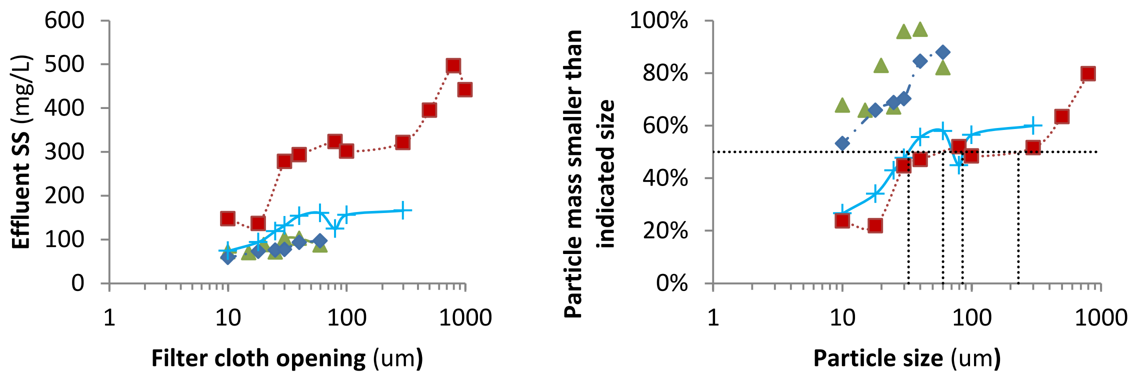

Figure 26). Although the composition differed, pH, conductivity, temperature, and DO were similar in all samples. The COD/TSS ratio was significantly higher for the more diluted samples. Such behaviour could be linked to the unload of septic tank water in the WWTP.

20150731 Influent SS = 106 mg/L
20150820 Influent SS = 227 mg/L
20150813 Influent SS = 101 mg/L
20150828 Influent SS = 647 mg/L

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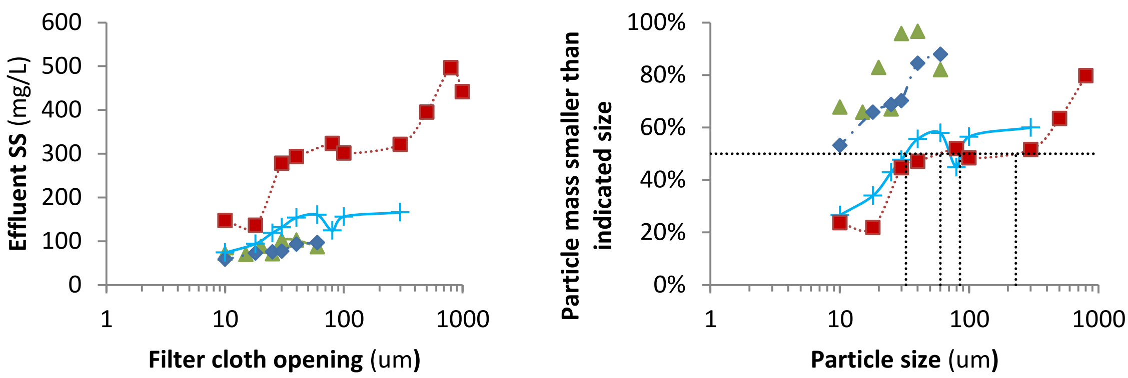

Figure 26: Particle size distributions at the Sjölunda WWTP measured in July-August 2016

For microscreens, high COD removal efficiencies can only be achieved in connection with high TSS removals (Remy et al., 2014; Vaananen et al., 2016). Therefore, it is required to have coagulation and flocculation tanks upstream the filter unit in Sjölunda in order to achieve performances similar to the current primary clarifier and HRAS system.

Jar tests were performed with different coagulation and flocculation agents. The flocculated water was later filtered through filtration cartridges with filtration clothes that could be installed in the Sjölunda filter unit. Overall, anionic polymers performed best in terms of filtration flux when a coagulant was applied. For filtrations with polymer flocculation only, cationic polymers generally performed better. TSS removal over 80% could be achieved through careful selection of the coagulant and the polymer in both cases.

Further lab tests with polymer pre-treatment and filtration showed that targeted TSS removals could be achieved by controlling the specific polymer dose in the jar test. However, polymer choice and wastewater composition remained important in order to target a more controllable TSS removal (Figure 27). Polymer doses should be linked to the influent TSS into the POWERSTEP plant.

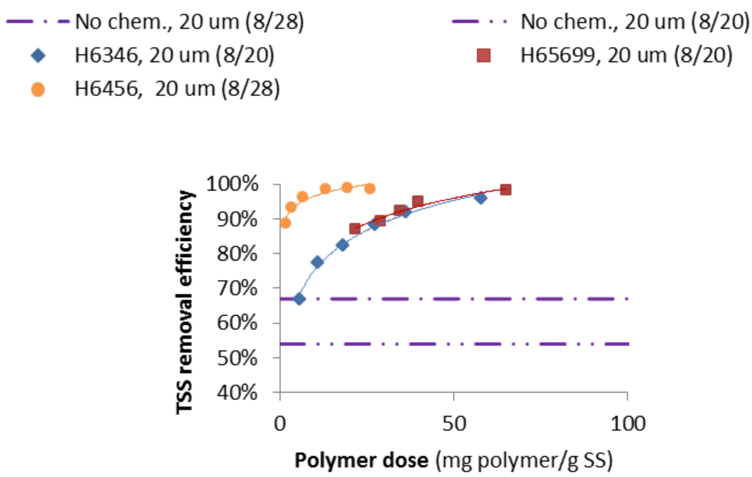

Figure 27: TSS removal efficiencies in benchtop tests performed with wastewater from the Sjölunda WWTP and jar tests with 3 different polymers

A more detailed study showed that TSS removal efficiencies up to 98%, total COD removal efficiencies up to 87% and TP removal efficiencies up to 94% could be obtained by adjusting the coagulant and flocculant doses in the jar tests. The tests also suggested potential for process control (Figure 28).

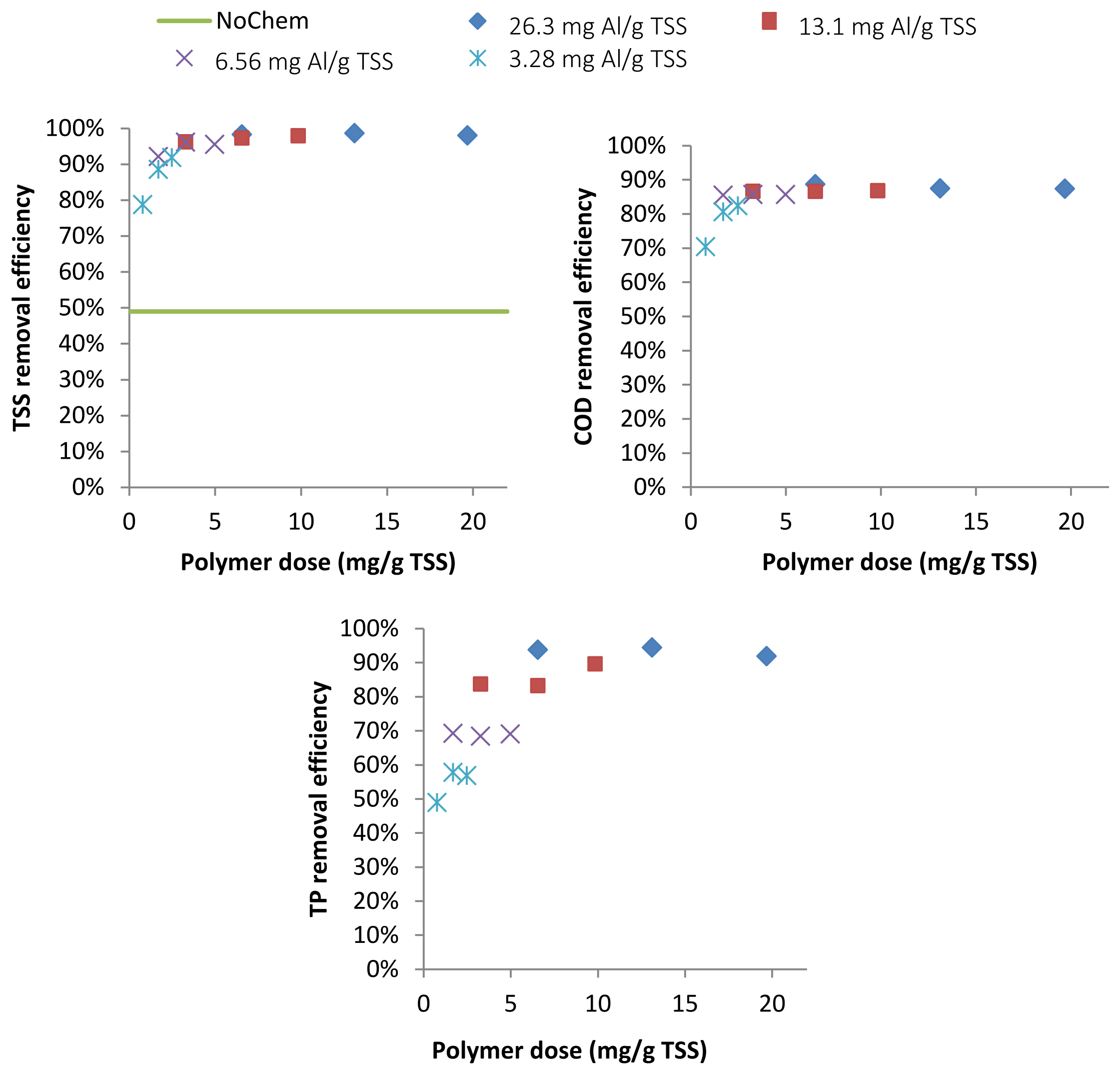

Figure 28: TSS, COD and TP removal efficiencies in benchtop tests performed with wastewater from the Sjölunda WWTP and jar tests with coagulant and flocculant

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5.4. POWERSTEP plant design for CS2

The POWERSTEP plant at the Sjölunda WWTP (Case Study 2) uses a Discfilter to explore the microscreen limits and maximize the hydraulic throughput in a minimal footprint. The test unit is installed on-site and will be commissioned during the winter 2016-2017. The water to treat is pumped directly from the effluent of the grit chamber. Pipes have been installed underground all the way to a test carp, which the WWTP operator has leased for the POWERSTEP project. The carp has heating, power and technical water supply, which helped to shorten the time required for the construction of the microscreen plant (Figure 29 and Figure 30).

Figure 29: Grit chamber effluent (left) and pipework towards the Discfilter plant (right)

Figure 30: Exterior and interior of the experimental carp leased by the Sjölunda WWTP operator

The planned layout for the filter unit in CS2 can be seen in Figure 31. The pumped wastewater will be led directly to a Drumfilter equipped with a 2 mm mesh in order to protect the Discfilter equipment from residual sand and grit, and to ensure robust operation throughout a long period of time. Coagulation and flocculation are performed on demand in the same fashion as presented in CS1. The flocculated primary wastewater is led by gravity into the influent of a HSF2200-C Discfilter, which has been adapted to the treatment of water with high suspended solids concentrations. A 100 µm cloth was selected in order to ensure a high treatment capacity. The installed unit is expected to reach a full treatment capacity of 500 m^3/h in a footprint of less than 10 m^2, even though tests will be run at around 50 m^3/h. The filter will also be equipped with automatic high pressure and chemical cleaning. Both filtrate and sludge from the Disc and the

Drumfilter will be pumped by gravity into two separate buffer tanks. Filtrate will be pumped further to the biofilm reactors for N removal and sludge will be disposed in a sludge storage tank or further thickened/dewatered to achieve dry solids contents ranging from 5 to 20%.

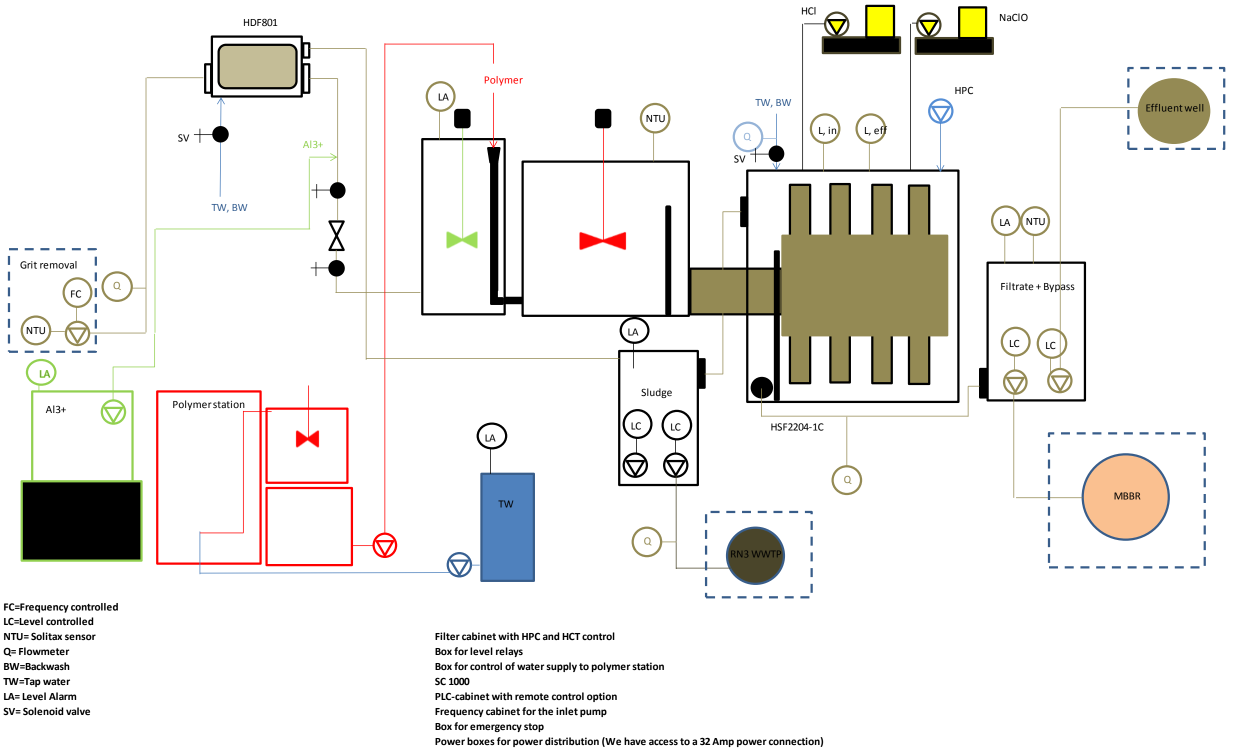

Figure 31: Layout inside the experimental carp at the POWERSTEP plant

The polymer station is analogous to the one presented for CS1 and a tap water buffer tank will also be used in order to ensure stable water pressures during polymer preparation. Coagulant will also be stored in an IBC tank placed over a spill pallet.

The plant can be controlled through the provided control cabinets in the filter, and coagulation and flocculation basins. Turbidities in influent, effluent from the flocculation tank, and filtrate, treated flows, backwash frequencies, dosing rates, sludge production, energy and water consumption will be logged for further data analysis. Performances and alarms can be monitored online through the installed gsm module.

5.5. Novelty in POWERSTEP

The presented case study in the Sjölunda WWTP will bring the following innovations to the use of Discfilters for primary treatment:

- It will be the first reference of primary treatment for the new HSF2200 Discfilter compact model, which features a reduced footprint through an optimization of the driving force in the filter unit.
- Additional mechanical modifications have been introduced in order to ensure robust continuous operation of the Discfilter. This will be the first primary treatment reference with Discfilters with a continuous wastewater feed throughout the year.

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- Self-cleaning nozzles will be used for the first time in order to minimize the maintenance need, and to allow the use of filtrate as backwashing media.
- 100 µm screens were selected instead of 40 in order to explore the hydraulic limits of the technology and reduce the footprint to the minimum.
- Different thickening equipment will be incorporated into the treatment train in order to benchmark what is the best available thickening technology compatible with Discfilters.

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