Deliverable 3.1 – Peer review report

WP3 – Installation of demonstration units

Background

Micropollutants, or contaminants of emerging concern, referring to a number of various substances such as pharmaceuticals, biocides and endocrine disruptors, may have adverse environmental effects, especially in cases with sensitive recipients. Besides impacts on aquatic life, release of micropollutants is a threat to drinking water resources in areas where access to fresh water for drinking water production is limited.

The reduction of the plethora of micropollutants that reaches the wastewater treatment plants from industries, households and hospitals is poor for many micropollutants. This makes the wastewater treatment plants point sources for several substances, for example pharmaceuticals. Therefore upgrading of wastewater treatment plants, with a fourth treatment step or alternative process solutions, will be needed. Advanced treatment for removal of micropollutants will also enable reuse of water for various purposes.

With LESS IS MORE the goal is to demonstrate removal of micropollutants at wastewater treatment plants around the Baltic Sea. Three different pilots will be installed at three different locations in three different countries – in Lithuania (Kretinga Water Utility), in Denmark (Slagelse Water Utility) and in Sweden (Svedala municipality).

Understanding GAC filtration

The core process and the common denominator of the pilot plants is GAC (Granular Activated Carbon) filtration. With GAC filtration a broad spectrum of micropollutants can be *removed* from wastewater, as opposed to ozone treatment where the micropollutants are *transformed*. The handling and operation of GAC is straightforward and the technology can be readily introduced at many wastewater treatment plants. Replacing or regenerating exhausted activated carbon is necessary when a pre-defined removal efficiency, of one or several target substances, no longer can be maintained, i.e. when there is a *breakthrough*. However, production (and regeneration) of activated carbon is energy demanding and costly. A filter that can be operated with sufficient removal efficiency for as long as possible is therefore desirable, and will of course lead to lower costs. Operational time (sometimes expressed as the number of bed volumes filtrated) is identified as a key parameter in development of competitive GAC processes. The main question to be answered based on the pilot trials is therefore:

How can the operational time, before reaching breakthrough, be maximized?

Pre-treatment steps and the overall characteristics of the GAC-filter are critical factors influencing the operation efficiency of a GAC-filter. Preceding treatment steps will for example influence the TOC (total organic carbon) and DOC (dissolved organic carbon) reaching the filter. Organic carbon (TOC and DOC) might influence clogging of the filter but also the development of a biofilm, which in turn could influence capacity and removal efficiency. Another critical parameter is the filter media itself, the GAC, which should be carefully selected.

The evaluation criteria for sufficient removal in the GAC-filter and for determination of breakthrough can be based on a pre-set removal efficiency with the target of removing at least (for example) 80% of each substance. Another approach is to base the evaluation criteria on the reduction needed to reduce the discharge of micropollutants below the effect values for water living organisms in the recipient. The effect values are expressed as Predicted No-Effect Concentrations (PNEC) for each of the selected target substances.

Objective

With the pilot tests the objectives are to demonstrate far-reaching removal, based on either a pre-set condition for removal or on removal sufficient to achieve PNEC-values, to increase understanding of the removal mechanisms in GAC-filtration and to develop strategies for maximising operational time of GAC-filters.

Advanced treatment with this approach might allow for reclamation of water as well as nutrients.

The pilot plants

The pilot plants in Slagelse and Kretinga are based on GAC as a final and additional treatment step, basically a fourth treatment step. In Svedala an innovative concept based on DMF (Direct Membrane Filtration) and GAC-filtration will be developed and demonstrated. The DMF-concept is described in Hey et al. (2016) and the pre-treatment in Väänänen et al. (2017)

The Danish pilot in Slagelse

The Danish pilot concept is based on polishing of biologically treated wastewater followed by adsorption of pharmaceuticals and other micropollutants in a column packed with granular activated carbon (GAC), see Figure 1 below.

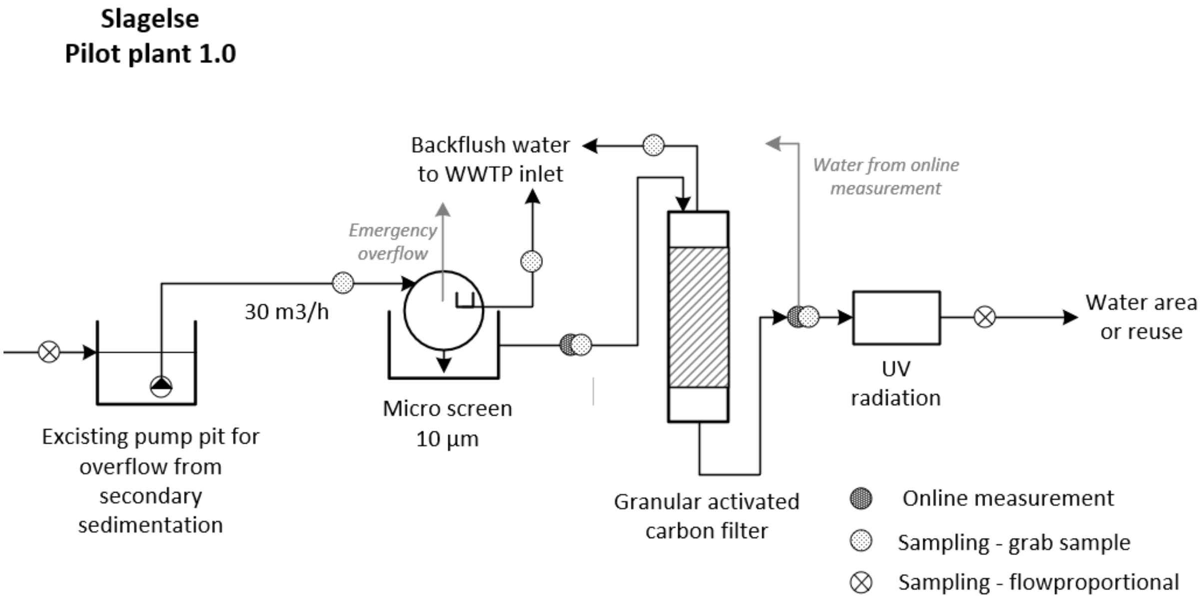

Figure 1. Concept for pilot tests in Denmark.

The GAC filter is sensitive to suspended solids in the feed water, as suspended solids can clog the column to a higher or lesser extent, causing reduced capacity. An important part of the treatment concept is therefore to test different pre-treatment strategies (microscreening with 10 µm or microfiltration with 0.2 µm) in order to optimize the performance in the GAC-filter. This installation can be used, together with UV radiation, to produce water for irrigation or for technical purposes at the wastewater treatment plant. Reuse of treated water is planned for irrigation and other local uses.

The Swedish pilot in Svedala

In the Swedish pilot unit direct membrane filtration (DMF), an innovative concept combining removal of organic matter, nutrients (preferably phosphorus) and micropollutants, will be demonstrated, see Figure 2 below.

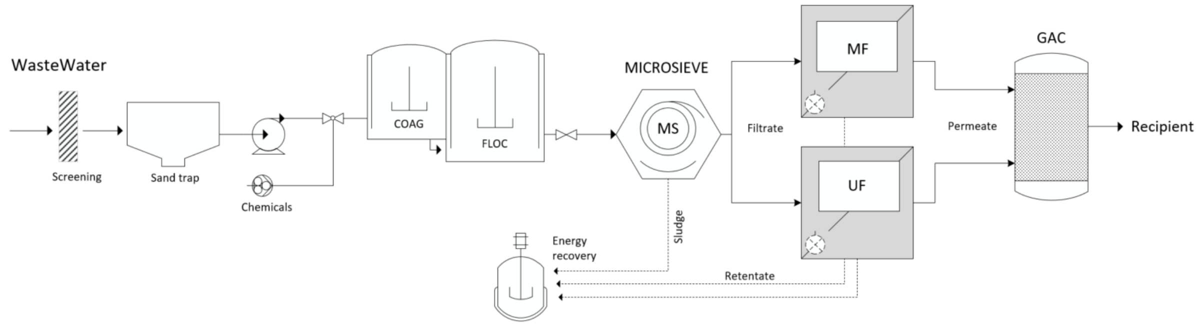

Figure 2. Concept for direct membrane filtration.

Different aspects related to the direct membrane filtration concept will be evaluated including energy recovery from sludge and reject water from the membranes.

DMF has previously been successfully tested. With this pilot the concept will be optimized and complemented with GAC-filtration for removal of micropollutants. Compared to the other pilots this GAC-filter will be loaded with water that has not passed biological treatment, which will influence the TOC (DOC) content and the characteristics of the organic matter. Bot microfiltration (MF) and Ultrafiltration (UF) will be evaluated.

The Lithuanian pilot in Kretinga

At Kretinga WWTP in Lithuania, deep-bed type up-flow filter with granulated activated carbon (GAC) will be installed downstreams secondary and tertiary treatment. The pilot unit will be evaluated during operation and if needed, an additional ozonation unit will be installed to increase removal efficiency of pharmaceuticals and other micropollutants. Figure 3 illustrates the concept.

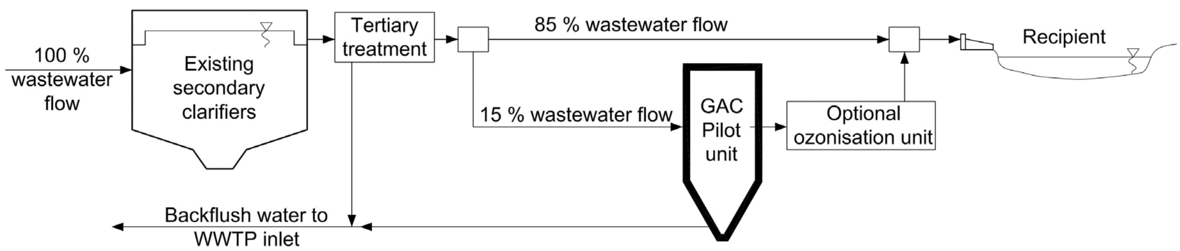

Figure 3. Concept for pilot tests in Lithuania.

Analysis of micropollutants

Micropollutants will be analysed at the laboratory for organic trace analysis at Kristianstad University. The selection of substances are based on lists from the European Union and national control documents, for example the Danish regulatory framework/tool for wastewater regulation of hospitals and the list of environmental indicators presented by the Swedish Medical Product Agency. The final list of pharmaceuticals chosen for evaluation, considering the above mentioned documents, chemical properties and chemical load to the treatment plants, are as follows:

	Compound Name	ATC
1	Amoxicillin	J01CA04
2	Atenolol	C07AB03
3	Azithromycin	J01FA10
4	Bendroflumethiazide	C03AA01
5	Carbamazepine	N03AF01
6	Ciprofloxacin	J01MA02
7	Citalopram	N06AB04
8	Diclofenac	D11AX18
9	Doxycycline	J01AA02
10	Erythromycin	D10AF02
11	Estrone	G03CA07
12	Fluconazole	D01AC15
13	Furosemide	C03CA01
14	Ibuprofen	C01EB16
15	Imidacloprid	
16	Ketoconazole	J02AB02
17	Losartan	C09CA01
18	Methotrexate	L01BA01
19	Metoprolol	C07AB02
20	Naproxen	G02CC02
21	Octyl methoxycinnamate	D02BA02
22	Oxazepame	N05BA04
23	Paracetamol	N02BE01
24	Penicillin G	J01CE01
25	Penicillin V	J01CE02
26	Perfluorooctanesulfonic acid	
27	Perfluorooctanoic Acid	
28	Propranolol	C07AA05
29	Sertraline	N06AB06
30	Sulfamethoxazole	J01EC01
31	Theophylline	R03DA04
32	Tramadol	N02AX02
33	Trimethoprim	J01EA01
34	Venlafaxine	N06AX16
35	Zolpidem	N05CF02

This list will be used as a starting point and could be considered as a “long list”. During the project it is perfectly possible to reduce the list depending upon results achieved. Such changes will be discussed in the project group.

Certain substances have the same function or “mode of action”, for example Atenolol, Metoprolol and Propranolol. However, they can show different PNEC values. Such cases should be further investigated and discussed.

Antibiotic resistence will be measured in Denmark, preferably in connection with the Danish pilot but possibly also for the other pilots.

Estradiol and Bisfenol are two substances in focus in Denmark. They can be measured but are also problematic to analyse. Estrone will be analysed and used as indicator. In a similar way, PFOS and PFOA can be used as model substances for perflourinated compounds.

Design data

Design data for the different pilots are summarized in Table 2. Design of the pilot plants, preferably selection of carbon and sampling strategies have been carefully discussed in separate project meetings. Specific details for the different pilots can be provided upon request. Figure 4 illustrates the pilot plant in Svedala, Sweden.

Figure 4. The pilot plant in Svedala, Sweden. The left picture shows the drumfilter, the equalization tank, the membrane unit (black) and the GAC-filters with equalization tanks in blue at the far end. The right picture illustrates the membrane unit.

Table 2. Influent refers to expected/estimated values in the influent to the GAC-filter

	Slagelse	Kretinga	Svedala DMF	Svedala WWTP effluent
Influent DOC (mg/l)	9		40-60	10-15
Influent N-tot (mg/l)	3.96[1]		40-60	4-8
Influent P-tot (mg/l)	0.35[1]		<0.1	0.08-0.32
Influent COD (mg/l)	28.8[1]		80	20-35
SS (mg/l)	3.4[1]		0	7-11
Pilot flow (m^3/h)	30	22	0.05-0.1	0.05-0.1
Bed height (m)	3.5	5	0.54	0.54
Cross section area (m^2)	4.9	12.6 (d=2 m)	(d=0.22)	(d=0.22)
EBCT (min)	34	19[2]	15-20	15-20
Filtration rate (m/h)	6.1	1.8	1-3	1-3
Type of backwash water (BW)	Effluent from WWTP	Effluent from tertiary	GAC-filtrate	GAC-filtrate
Treatment of BW	Sent to inlet of WWTP	Sent to inlet of WWTP	To biological treatment	To biological treatment
Mass of carbon (kg)	7 480		9	9
Volume of carbon (m^3)		7		
Carbon type	Desotec Organosorb 20[4]	Aquasorb 5000 or Cyclecarb	Aquasorb 5000 and Cyclecarb 401	Aquasorb 5000 and Cyclecarb 401
Estimated energy use (kWh/m^3)	0.2	0.6	<0.6[3]	

[1]Average of 6 flow proportional 24-hours samples

[2]Based on the volume of carbon

[3]DMF including coag/flocc + microscreening + membrane + GAC

[4]Bituminous coal/ stream activation, Particle size 0.42 – 2.80 mm, Bed density 480 kg/m^3 BET N_2; Iodine number 800 mg/g

References

Hey, T. (2016) *Municipal wastewater treatment by microsieving, microfiltration and forward osmosis: concepts and potentials*. Water and Environmental Engineering, Department of Chemical Engineering, Lund University.

Väänänen, J. (2017) *Microsieving in municipal wastewater treatment. [Elektronisk resurs] : chemically enhanced primary and tertiary treatment*. Water and Environmental Engineering, Department of Chemical Engineering, Lund University.