less is MORE

# Pilot plant in Slagelse - Experiences with GAC and UV

09.03.2021

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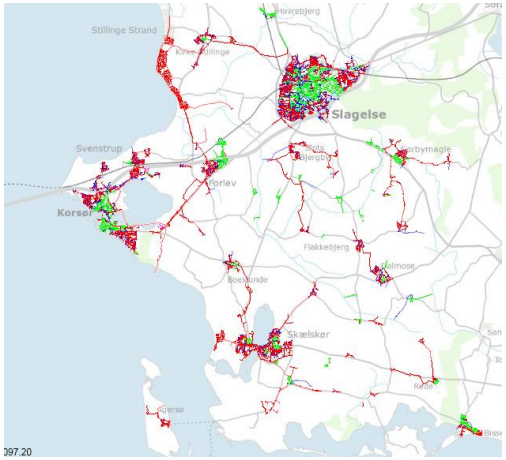
# Where are we?


**Municipality of Slagelse**

- 79,000 inhabitants
- 570 km2
- 32,000 in Slagelse City

**Slagelse Utility**

- Multi-utility company
- Operating three large scale and 24 smaller WWTP’s

**Water area**

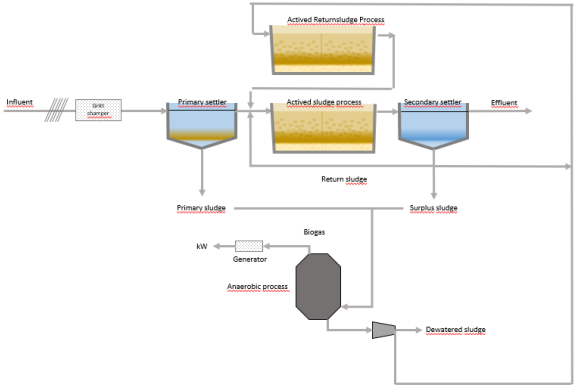
- Tude Stream
- Great Belt

# Focus of the project: Slagelse WWTP

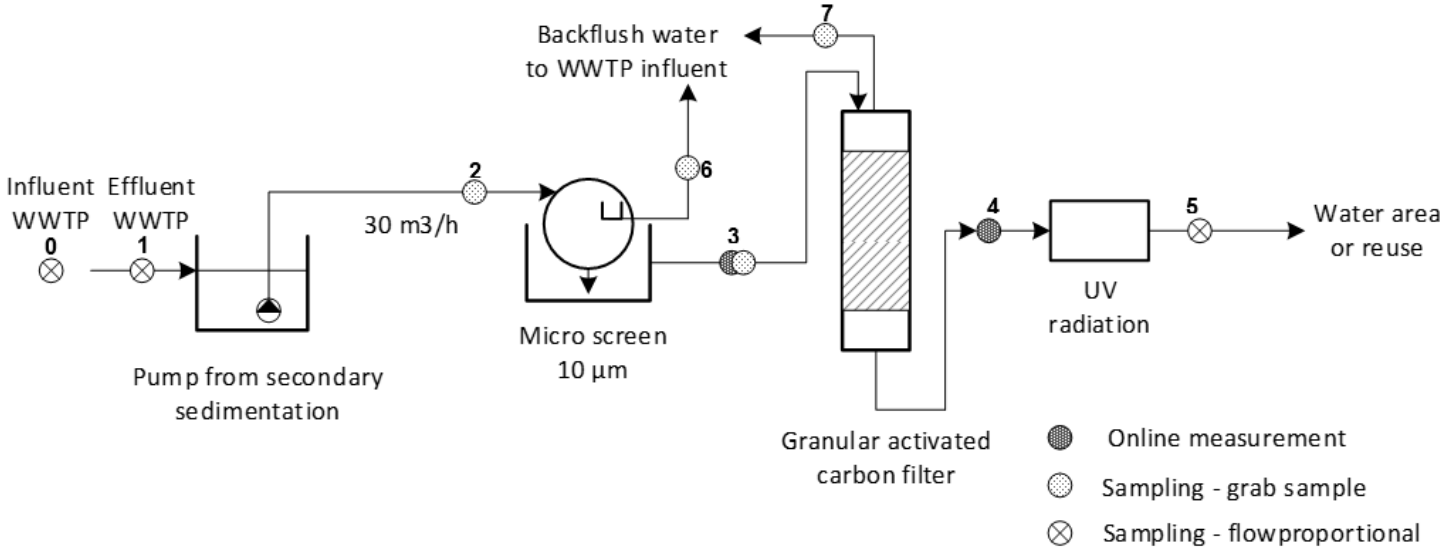
- Capacity 125.000 PE
- Daily load app. 60.000 PE
- Flow: 10,000 $m^3/d$
- Effectiveness of treatment
  - Organic matter 99%
  - Nitrogen 91%
  - Phosphorus 98%

- DOC in effluent: 7-9 mg/l

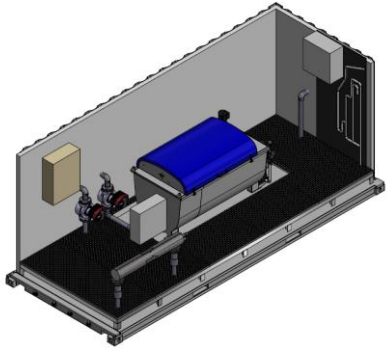
Sewer catchment:
- Slagelse Hospital (372 beds)
- Slagelse Psychiatric hospital (194 beds)

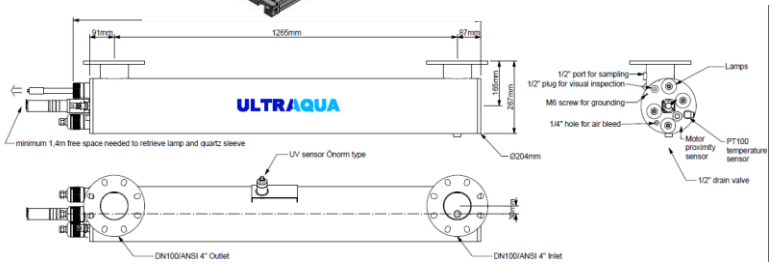



# Fourth treatment step - Pilot plant setup



# Key figures






- Test period from January 2019 to August 2020
- Design flow rate: 30 $m^3/h$
- Disc filter: 10 µm filtration
- GAC: 17 $m^3$
- UV design dose: > 40 $mJ/cm^2$, 4 lamps

- Total flow amount treated (august 2020): 255,000 $m^3$ or 14,900 BV
- Average electricity use: 0.24 $kWH/m^3$ (Microfiltration, pumps, GAC filtration, UV and online measurement)

# GAC filter with reactivated carbon

Reactivated carbon (Organosorb 20) was used

- Virgin fossil carbon: 11-18 tons $CO_2$-equivalents per tons produced
- Reactivated carbon: 2-3 tons of $CO_2$-equivalents per tons produced

= Carbon footprint: 6 times lower than virgin fossil carbon

Carbon particle size: 1.7 mm (0.42-2.8)

Filter: 17 $m^3$

EBCT was between 34 to 43 minutes

Carbon usage after 14,900 BV: 30 mg GAC/l

Backwashed six times:

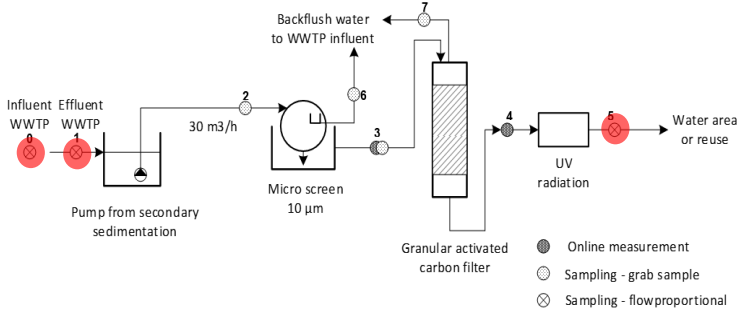
| Backwash | BV | Comments |
|---|---|---|
| 03-06-2019 | 2,323 | Treated wastewater. Sampling of backwash water after 15 minutes |
| 31-07-2019 | 3,769 | Treated wastewater. |
| 11-11-2019 | 5,987 | Treated wastewater. Sampling of backwash water after 5 and 10 min. |
| 04-03-2020 | 10,482 | Treated wastewater |
| 17-03-2020 | 11,044 | Treated wastewater |
| 07-07-2020 | 14,066 | Treated wastewater and air |

# Micropollutants and microbiology measured

## Micropollutants

- Laboratories: Kristianstad Uni. (S) and IUTA (G)
- 44 micropollutants (pharmaceuticals, industrial chemicals, pesticides and contrast media)

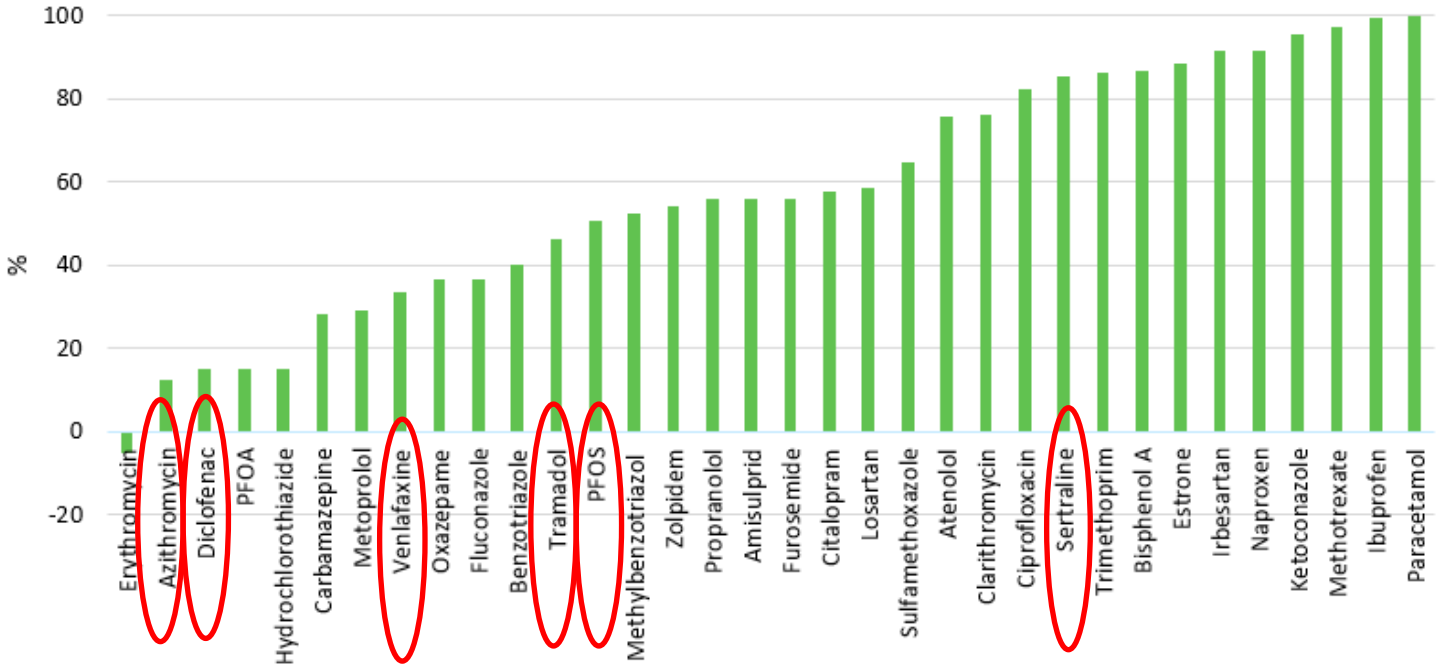
| | Number |
|---|---|
| Total number of analyses | 2,296 |
| Total number of analyzed parameters | 44 |
| Kristianstad parameters | 37 |
| IUTA parameters | 7 |



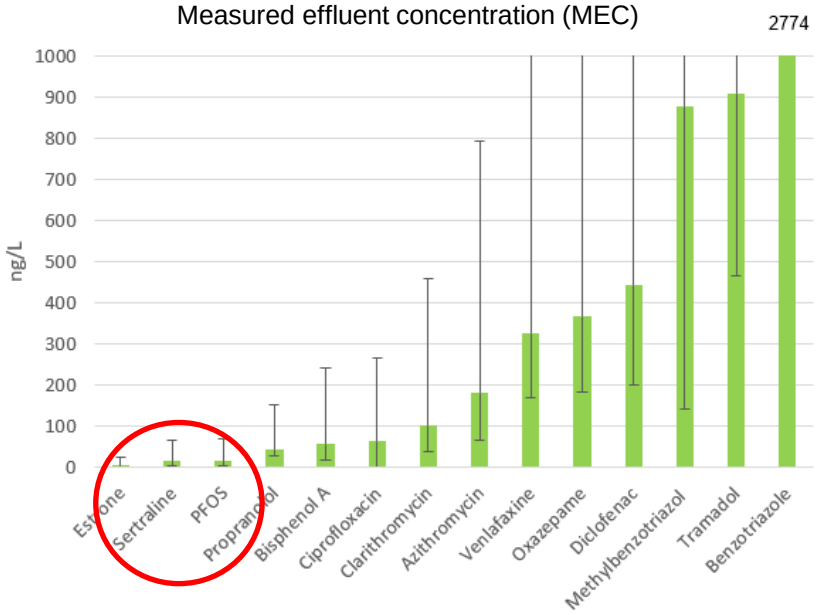

## Microbiology

- Laboratories: Slagelse Utility and DHI (antibiotic resistance)
- Culturable bacteria 22 °C and 37°C, Escherichia coli and Enterococci
- Vancomycin resistant enterococci (VRE), Carbapenem resistant Enterobacteria (CPE) and Cephalosporin Resistant E. coli (CEF)

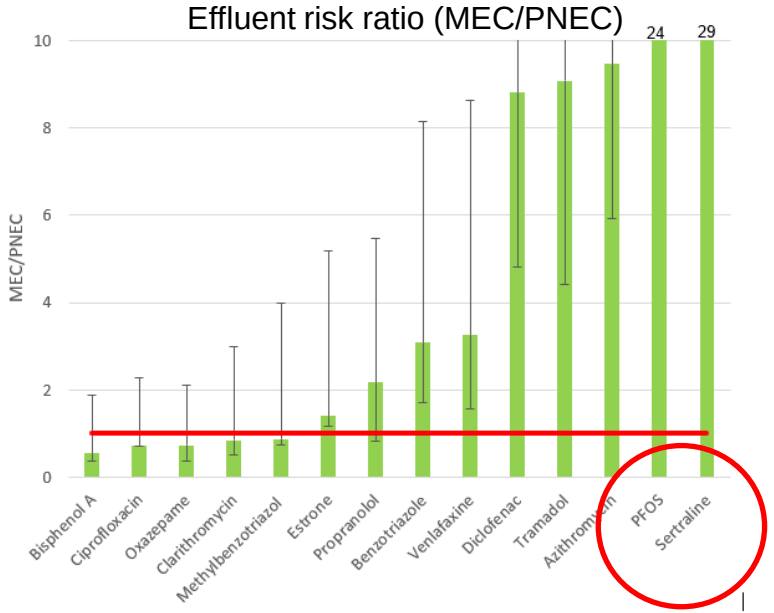
# Removal in the conventional WWTP



# Conventional WWTP effluent
# 14 critical micropollutants measured >$PNEC_{Freshwater}$



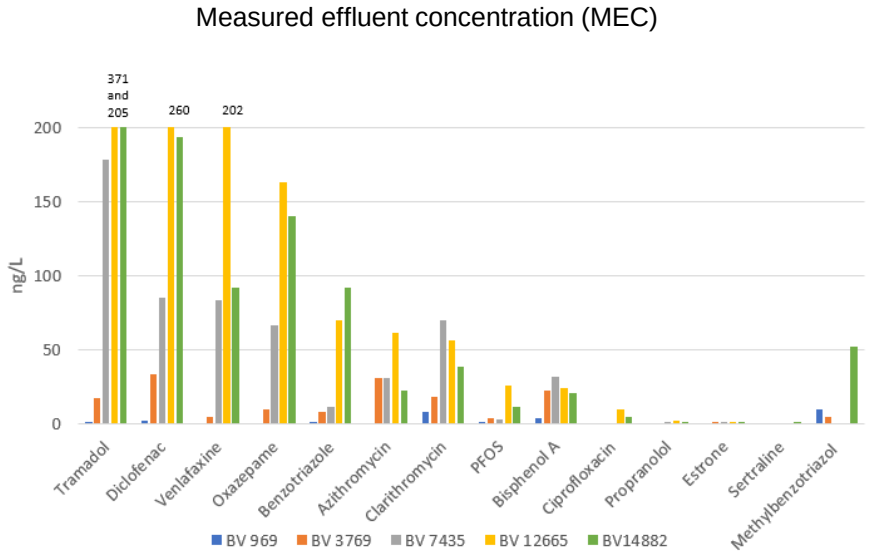

*Average concentrations of pollutants measured above $PNEC_{Freshwater}$.*

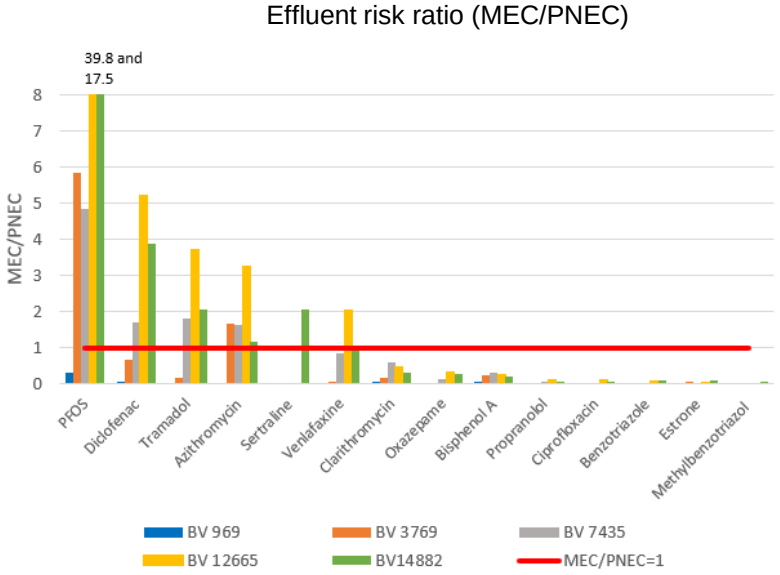



*Ratio between measured concentrations (MEC) and predicted no-effect concentrations ($PNEC_{Freshwater}$)*

# Pilot plant effluent

# 6 micropollutants measured >$PNEC_{Freshwater}$ after 14,900 BV

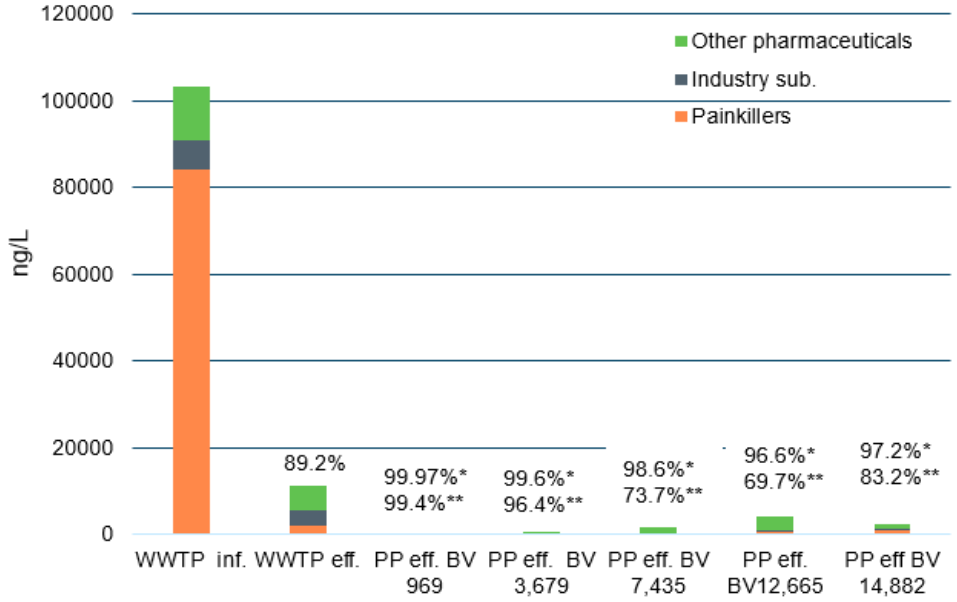



*Effluent concentration from pilot plant.*

*Ratio between measured concentrations (MEC) and predicted no-effect concentrations ($PNEC_{Freshwater}$)*

# Removal efficiency from WWTP influent to pilot plant effluent
## All 34 micropollutants

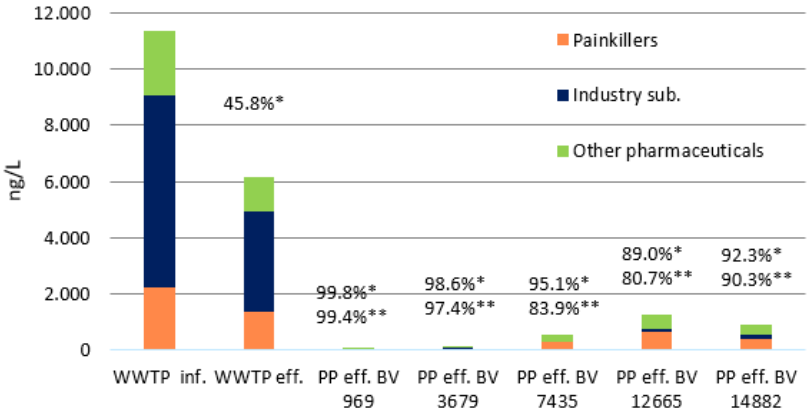



** Reduction of total concentration relative to WWTP inf.*

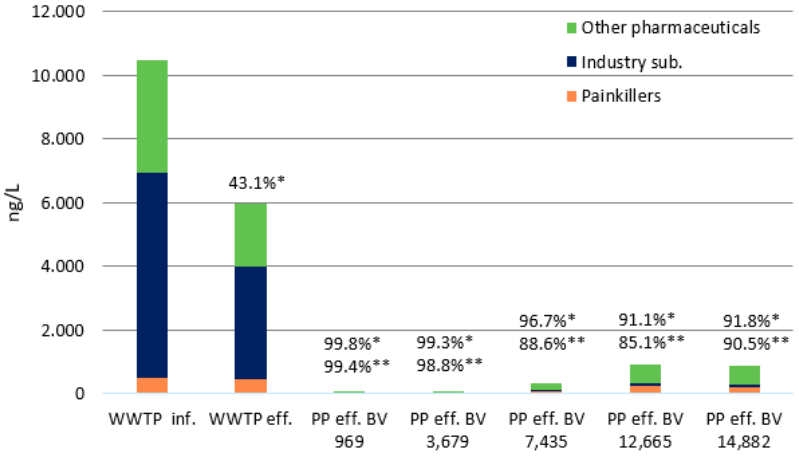
*** Reduction relative to WWTP eff.*

# Removal efficiency from WWTP influent to pilot plant effluent

## 14 critical micropollutants




## 11 Swiss substances




** Reduction of total concentration relative to WWTP inf.*

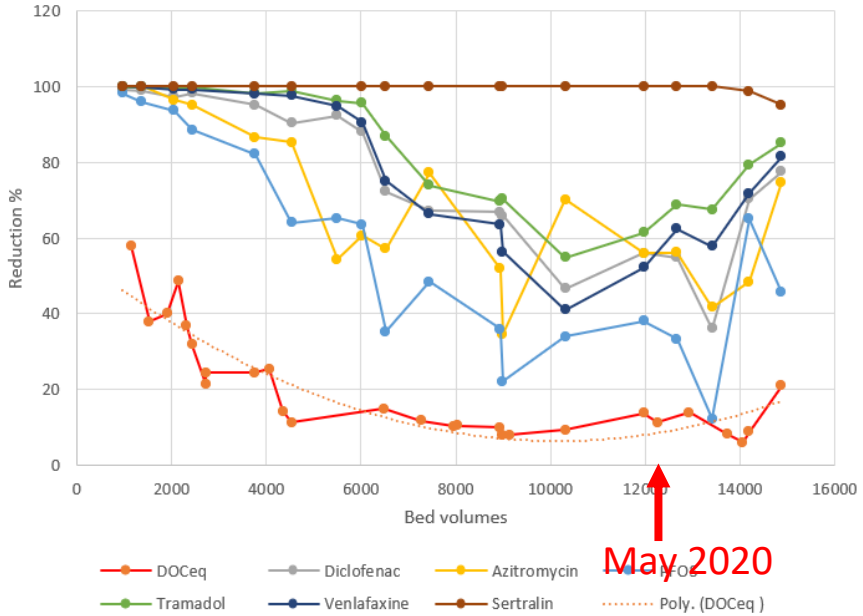
*** Reduction relative to WWTP eff.*

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

| | Conventional WWTP plus pilot plant removal percentage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **BV** | **969** | **2442** | **4541** | **6026** | **8986** | **10322** | **12665** | **14.882** |
| **Diclofenac** | 100 | 98 | 92 | 92 | 80 | 79 | 50 | 63 |
| **PFOS** | 99 | 97 | 75 | 73 | 92 | 90 | 16 | 63 |
| Oxazepame | 100 | 100 | 98 | 96 | 85 | 79 | 72 | 76 |
| Venlafaxine | 100 | 100 | 99 | 94 | 72 | 73 | 59 | 81 |
| Carbamazepine | 100 | 100 | 98 | 98 | 87 | 81 | 73 | 83 |
| **Tramadol** | 100 | 100 | 99 | 98 | 85 | 86 | 78 | 88 |
| **Azithromycin** | 100 | 91 | 88 | 70 | 68 | 88 | 70 | 89 |
| Clarithromycin | 98 | 95 | 89 | 90 | 86 | 82 | 87 | 91 |
| Metoprolol | 100 | 100 | 99 | 100 | 91 | 86 | 86 | 93 |
| Bisphenol A | 99 | 97 | 96 | 91 | 96 | 89 | 94 | 95 |
| Citalopram | 100 | 100 | 100 | 100 | 96 | 92 | 92 | 97 |
| Methylbenzotriazol | 98 | 98 | 99 | | | | | 97 |
| Benzotriazole | 100 | 100 | 100 | 100 | 99 | 98 | 98 | 98 |
| Ciprofloxacin | 100 | 100 | 100 | 99 | 100 | 98 | 97 | 99 |
| **Sertraline** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 |
| Propranolol | 100 | 100 | 100 | 100 | 99 | 95 | 98 | 99 |
| Estrone | 100 | 100 | 100 | 100 | 100 | 97 | 100 | 99 |
| Total removal 14 substances | 100 | 98 | 95 | 92 | 89 | 89 | 78 | 88 |

≥80%
50-80%
20-<50%
<20%

# GAC breakthrough of the 6 critical pollutants and DOCeq

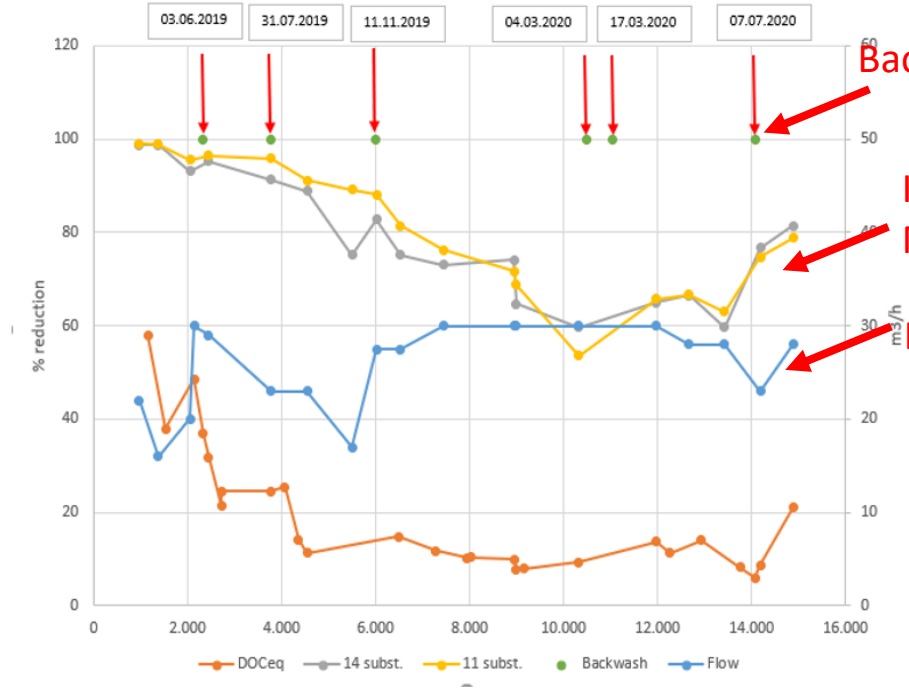



Probably biofilm formation in GAC

Change of adsorption and degradation properties

*Reduction of critical pollutants plus DOCeq in the pilot plant. The dotted line indicates the trend for the development of the DOCeq*

# Overview of GAC breakthrough of 14 critical substances and 11 Swiss substances




Backwash

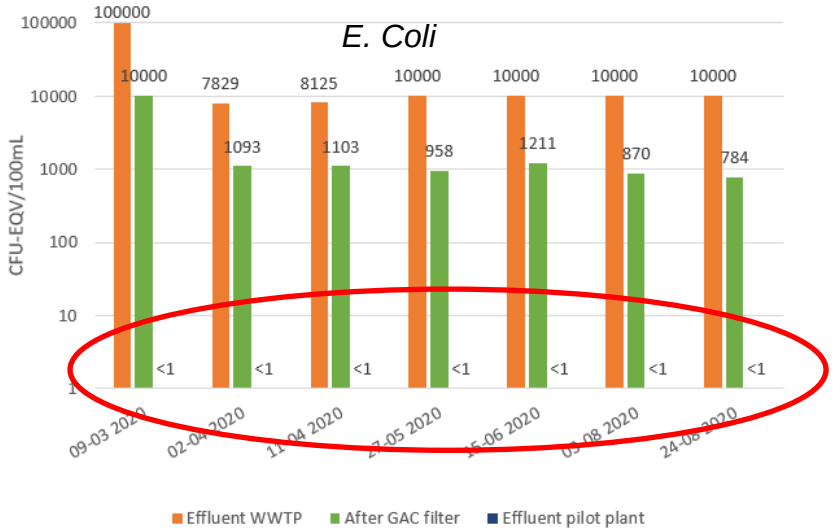
Improved removal from May to August 2020

Flow

# Disinfection by UV in pilot plant

## Results from WWTP effluent, after GAC and after pilot plant (PP)

- Efficient removal of *E. coli* and resistant bacteria
- PP effluent complies with Danish Drinking Water Act and EU regulation on reclaimed water for agricultural irrigation




Antibiotic resistant bacteria

| | Enterococci | | Coliform | | | *E.coli* | | |
|---|---|---|---|---|---|---|---|---|
| Unit | Total MPN/100 mL | VRE CFU/100 mL | Total MPNCFU/100 mL | CPE CFU/100 mL | CEF CFU/100 mL | Total MPNCFU/100 mL | CPE. CFU/100 mL | CEF CFU/100 mL |
| Influent WWTP | 950,000 | 13,000 | 42,500,000 | 455 | 369,500 | 1,690,000 | 182 | 92,350 |
| Effluent WWTP | 10,750 | 424 | 292,500 | <20 | 12,500 | 17,950 | <20 | 1,325 |
| After GAC | 1,520 | 49 | 17,500 | <20 | 675 | 2,185 | <20 | 237 |
| Effluent PP | <1 | <1 | <50 | <20 | <20 | <50 | <20 | <20 |

VRE: Vancomycin resistant enterococci
CPE: carbapenem resistant Enterobacteria
CEF: Cephalosporin resistant *E. coli*

*Sampled 27.02.2020.*

# Investment and operational costs

- Total pilot plant investment: 210,000 EUR
- Original budget was: 104,000 EUR. The expansion covered mainly new pumps and backwash system with air
- Man-hours for operation: 3 hours / week

**Estimate of future cost for full scale implementation**

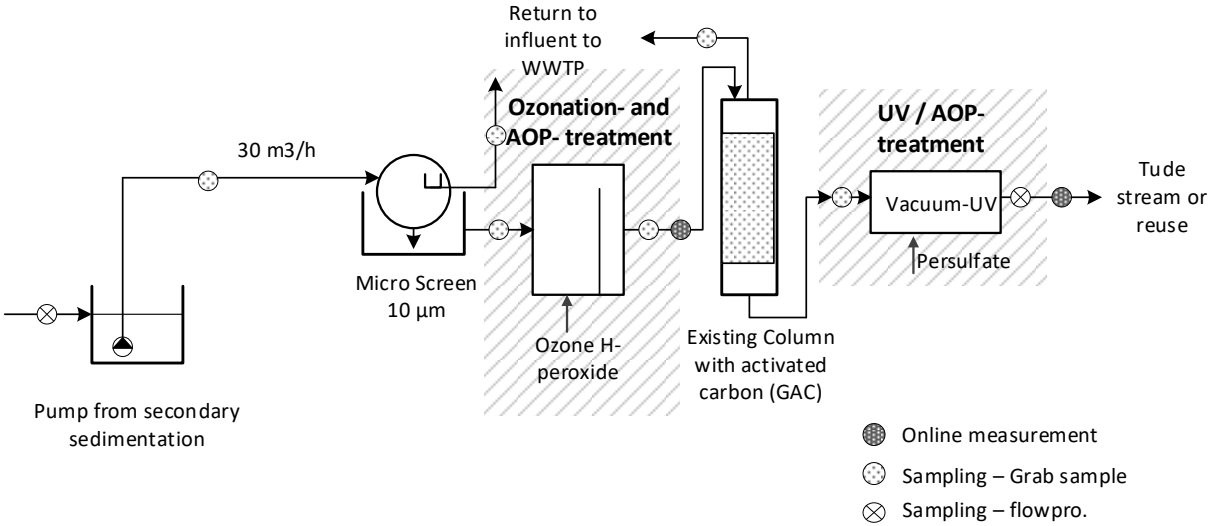
- Estimate based on a linear write-off over 15 years and assuming a GAC-filter loading of 46,000 BV (five filter shifts) which corresponds to a **carbon usage of 10 mg/l**
- Drum filter, building, pumps & pipes, GAC filter unit and UV: 120,000 EUR, and each GAC filter filling (including GAC transport costs) is estimated to 16,200 EUR.
- Including electricity consumption (0.013 EUR/m3) and manpower for maintenance (0.019 EUR/m3) the total estimate amounts to:

**0.088 EUR/$m^3$ (0.66 DKK/$m^3$)**

# Next steps in Slagelse

- A new project (OxyTreat) with expansion of the pilot plant with oxidation processes
- Funded by Danish EPA,  Time schedule: 2021-2022
- Planning is started – new technologies will be in place after summer holiday
- Full-scale solution are to be implemented before 2025

***New pilot plant setup***



# Most important takeaways

- Overall GAC was effective (≥80%) for removal of critical micropollutants
- 6 pollutants were breaking through after 15,000 BV
- Effluent complies with criteria from DK drinking water and EU regulation on water reclamation
- Total cost for full scale implementation is estimated to 0.088 EUR/$m^3$
- A new follow-up project (Oxytreat) are to reduce breakthroughs and increase GAC durability

# THANK YOU FOR YOUR ATTENTION!


**Ulf Nielsen, Ultraaqua A/S**

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ULTRAQUA GROUP

- altid i nærheden

SLAGELSE KOMMUNE