Start-up of aerobic granular sludge

Results of the first AGS start-up in the Nordic countries

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AGNES II - Implementation of aerobic granular sludge in Sweden – a full-scale study, SWWA project no. SVU 17-122

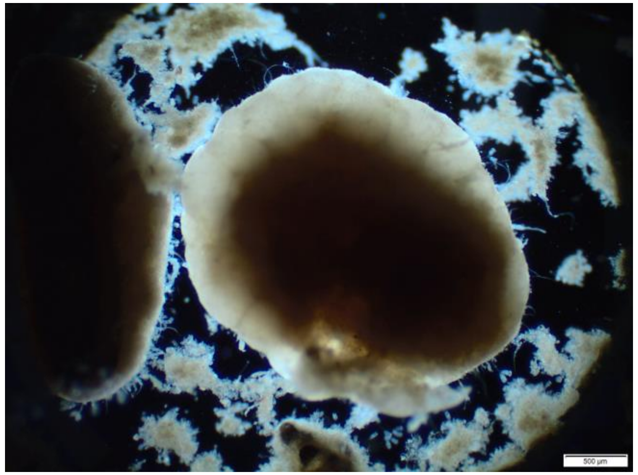
Aerobic granular sludge (AGS)

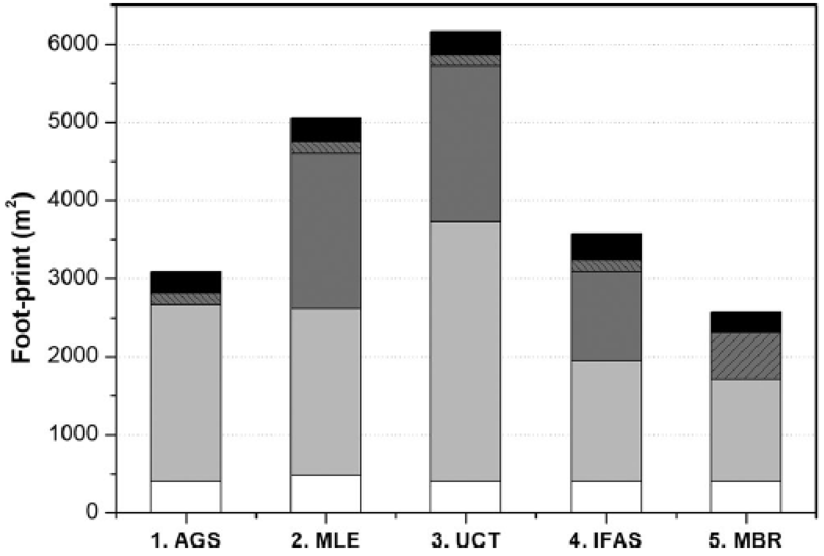
Granular sludge formed due to

- High feeding concentration
- Wash out of slow settling sludge
- Anaerobic feed favours slow growers

AGS opens the door for

- Compact **and** energy efficient treatment
- Simultaneous C, N, P removal



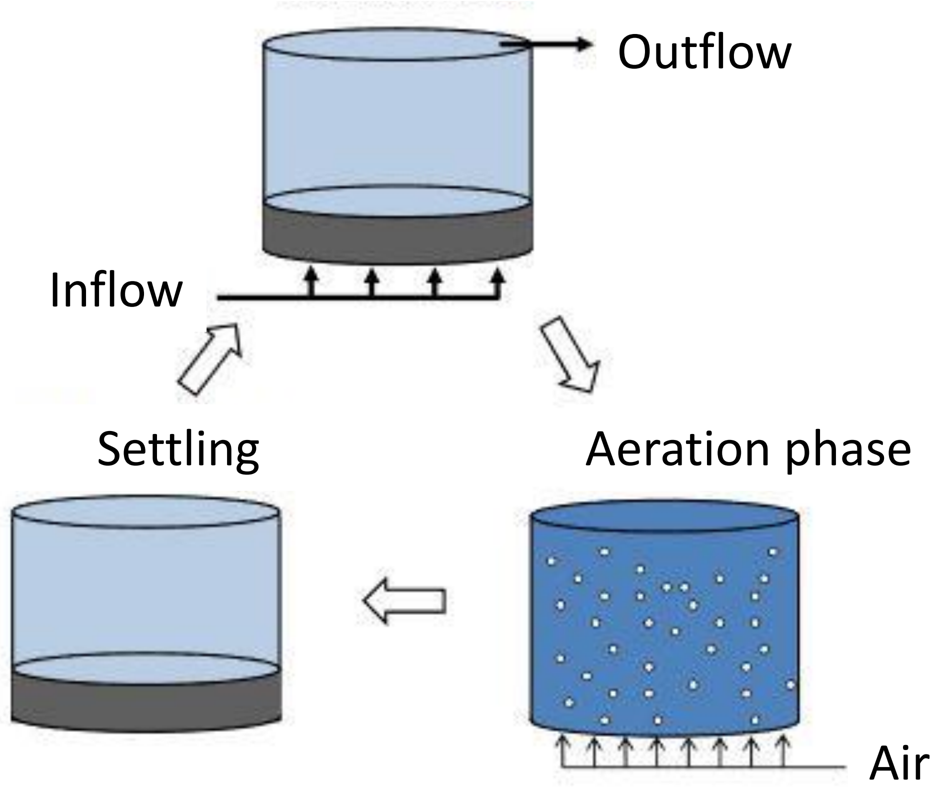


Bengtsson *et al.* (2018)

Nereda® technology

Optimised SBR cycle:

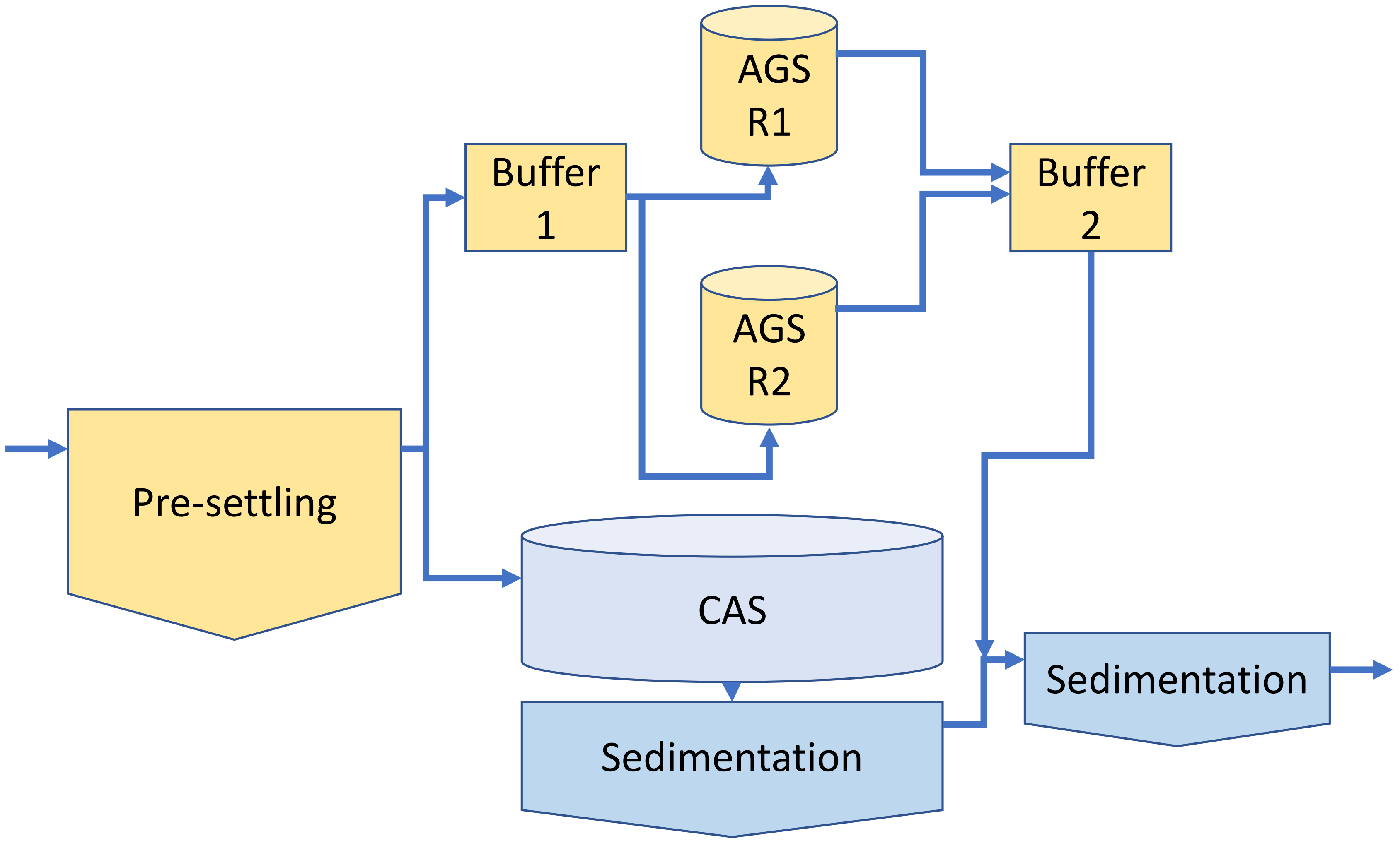
- Simultaneous influent feed and effluent discharge
- Simultaneous biological removal of organic, nitrogen and phosphorus components
- Fast settling phase



Picture: Bengtsson et. al. 2017

Österröd WWTP in Strömstad, Sweden

- Reconstruction to increase capacity
- AGS and conventional activated sludge (CAS) in parallel
- Pre-settling added
- Design: 30,000 PE (max in summer)
- Biological treatment capacity 600 m^3/h (60% to AGS)



Start-up of AGS

Start-up under real conditions have challenges

- Availability of granulated sludge/selection of activated sludge for seeding
- Operation to ensure both granulation and sufficient treatment

Over 30 full-scale AGS have been started up, but not many are scientifically documented

General challenges specific at Österröd WWTP

- Low temperatures during winters
- Large load variations
- Long lasting high flows
- Incoming load > the design (CAS under reconstruction during start-up)

Objective

Evaluate the start-up of the first AGS in the Nordic countries in terms of

- Inoculum
- Granulation
- Process performance
- Microbial community development
- Influence of local conditions

Methods

- Chemical analyses
- MLSS, SVI and granule size distribution
- Cycle studies
- Activity batch tests
- DNA and FISH analysis

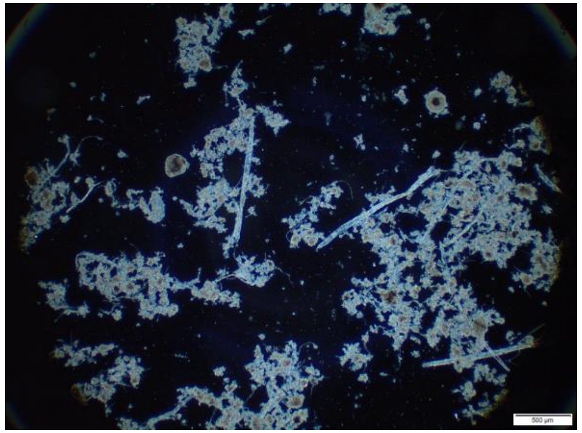
Picture: measurement of granule size distribution

Start-up at Österröd WWTP

Start-up date: 26 June 2018
Study period: – August 2019

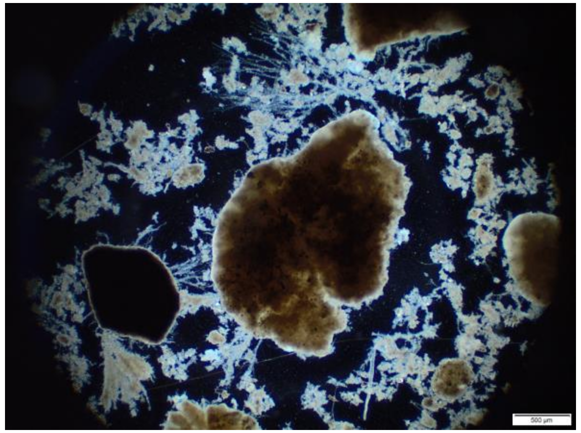
Reactor 1

- Swedish activated sludge, SBR with bio-P
- Start conc 3.4 g/L



Reactor 2

- Aerobic granular sludge from the Netherlands
- Start conc 3.6 g/L



Strategy

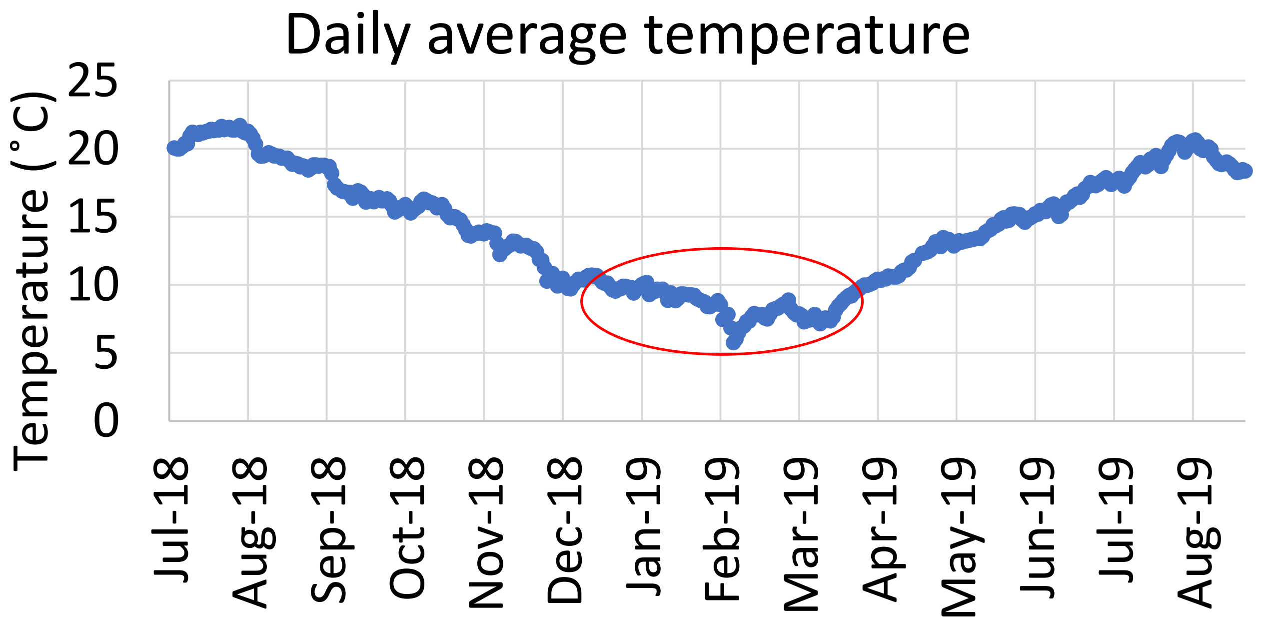
- Gradual flow load increase

Wastewater characteristics

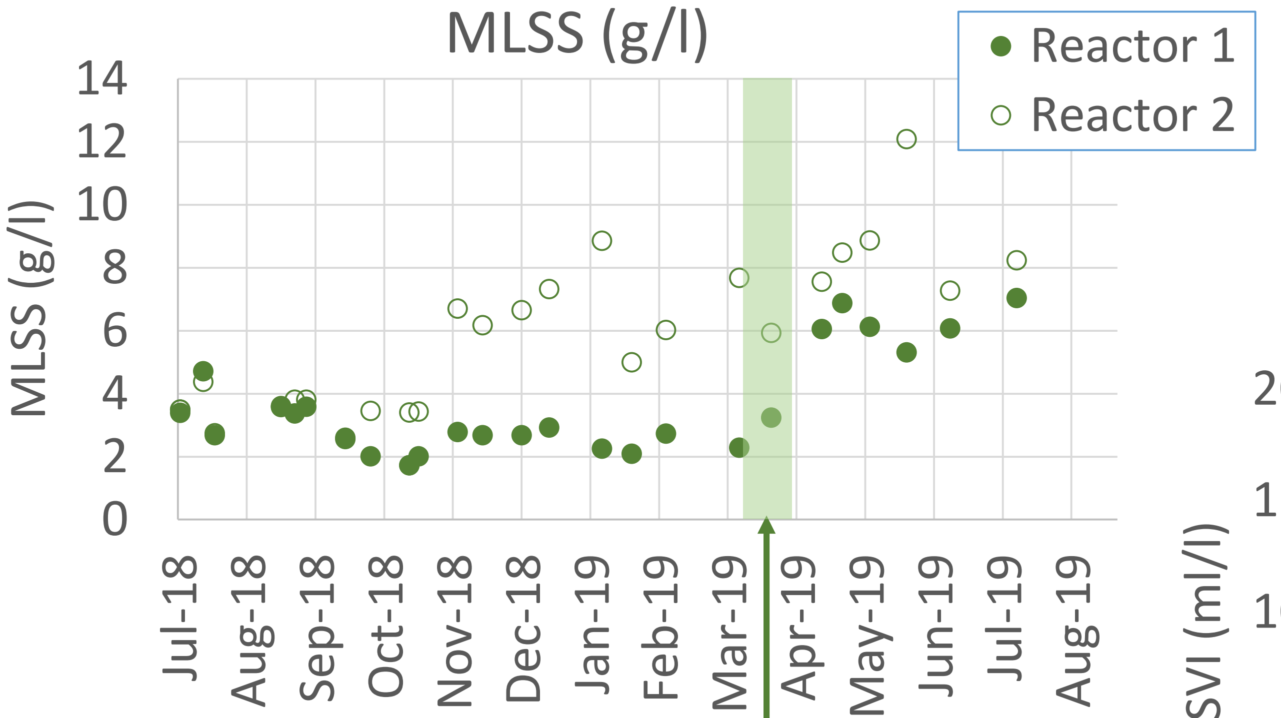
Flow proportional averages	Flow	BOD_7	COD	COD filtered	P_{tot}	N_{TKN}	NH_4^+-N
	m^3/d	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
July - August	2000	140	350	190	5.6	56	51
September - June	3800	66	160	74	3.3	33	26

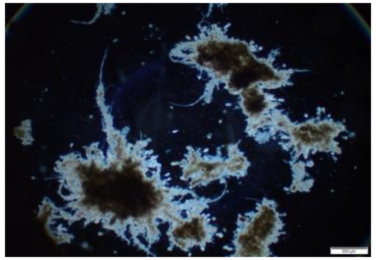
	BOD_7/ N_{TKN}
Jul - Aug	
Average ± SD	2.6 ± 0.7
Sep - Jun	
Average ± SD	2.0 ± 0.6

Many samples are grab samples

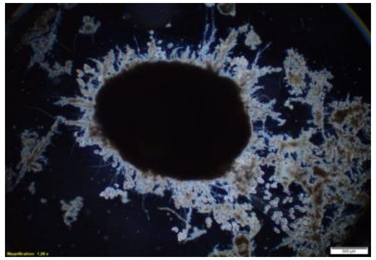


Results – sludge characteristics

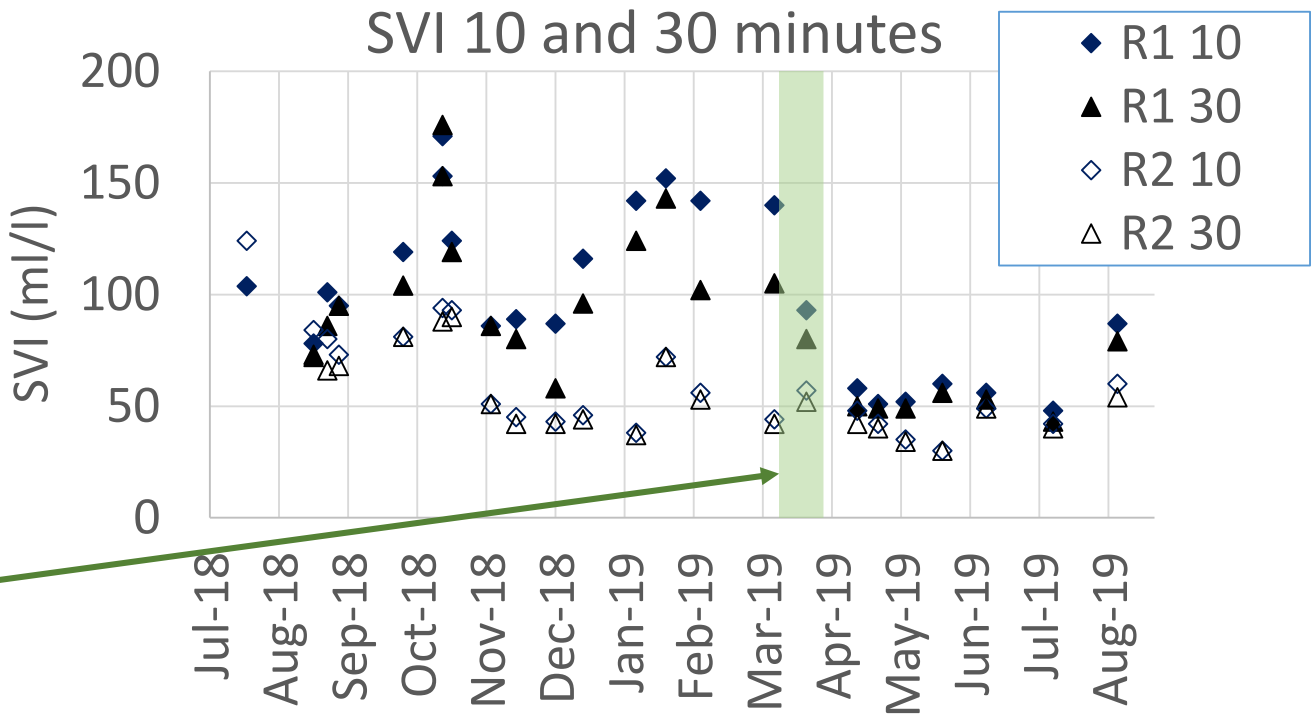




Reactor 1



Reactor 2

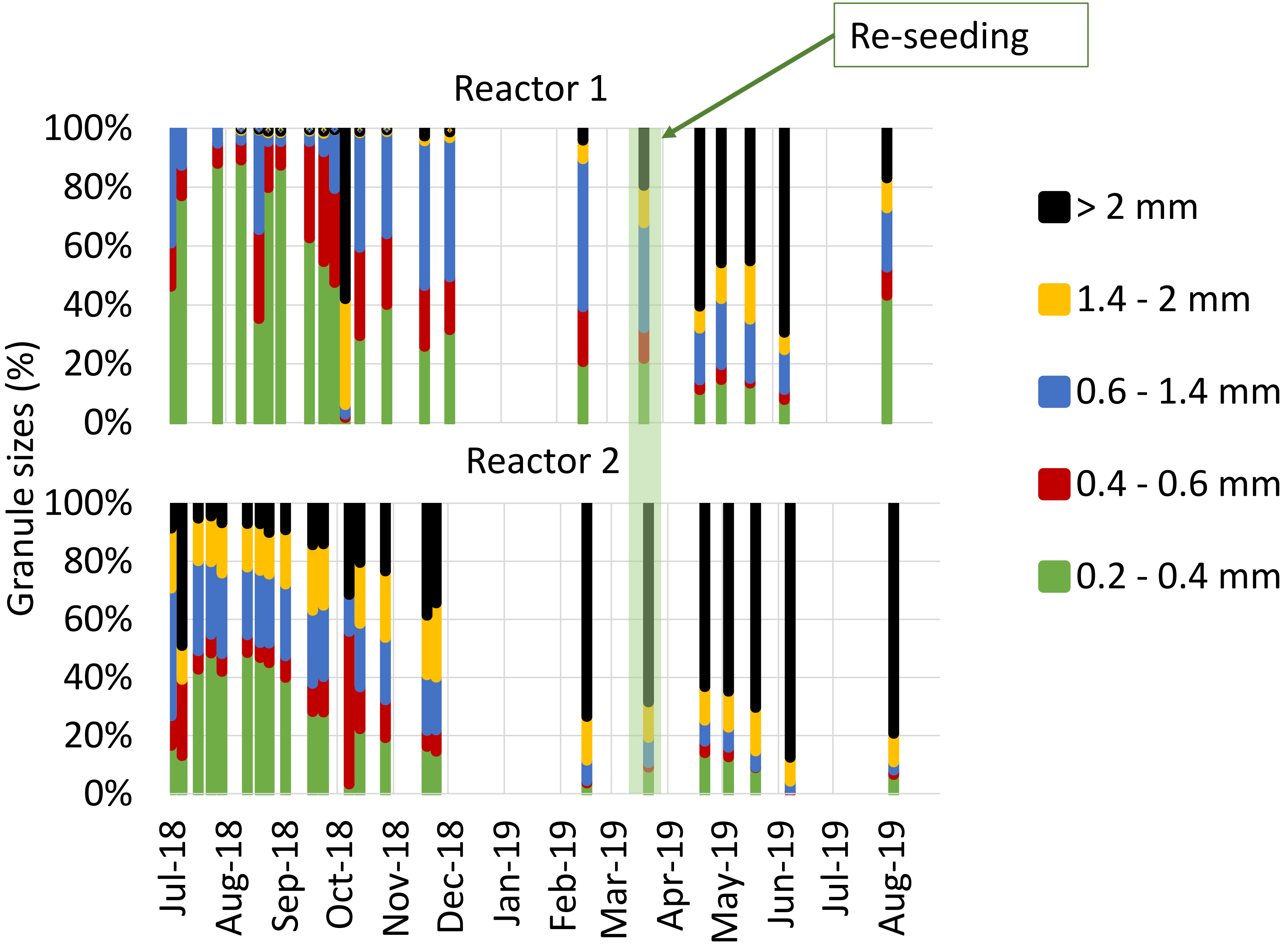


Re-seeding reactor 1 from reactor 2

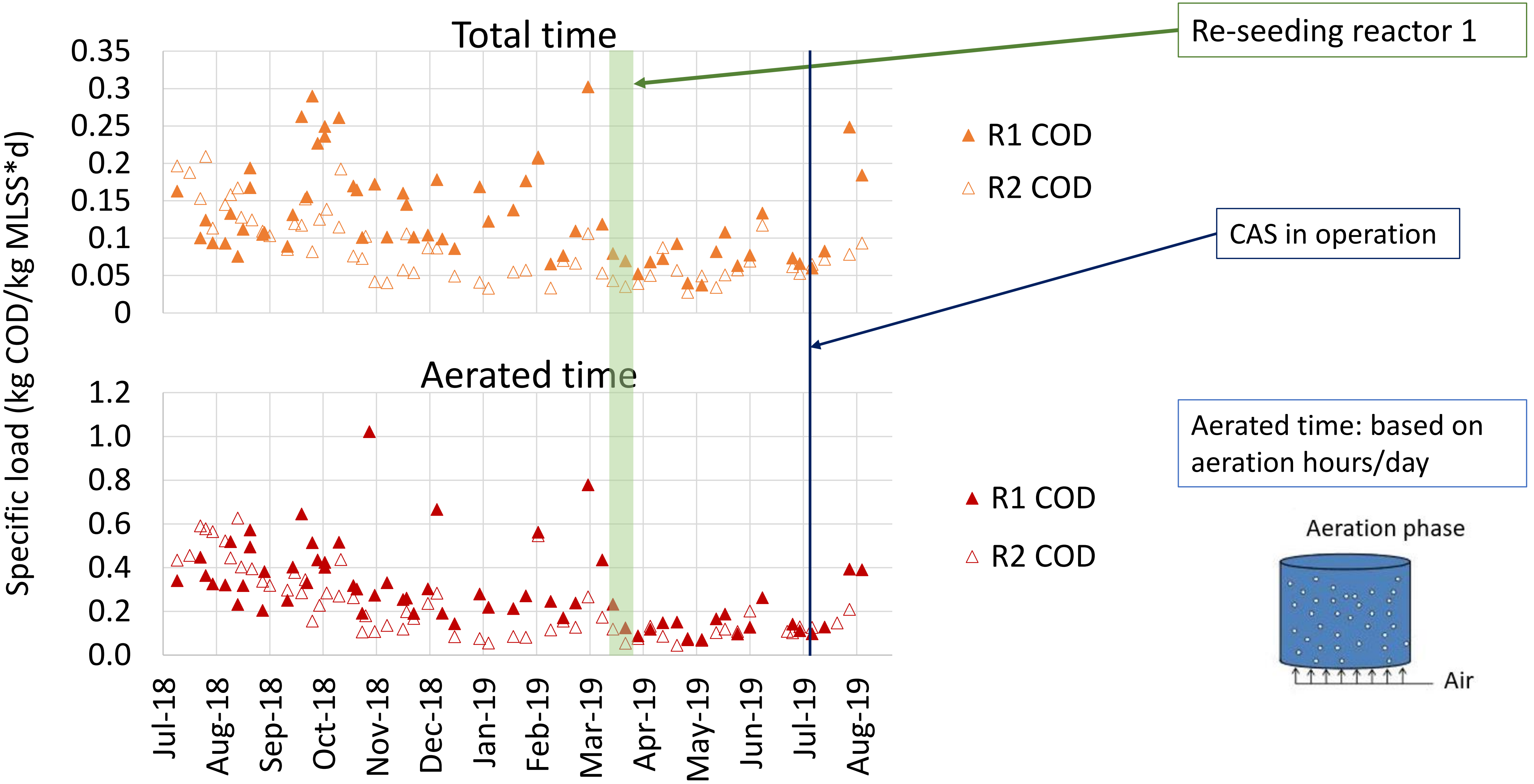
Results - granule size distribution

Reactor 1: more large granules after re-seeding

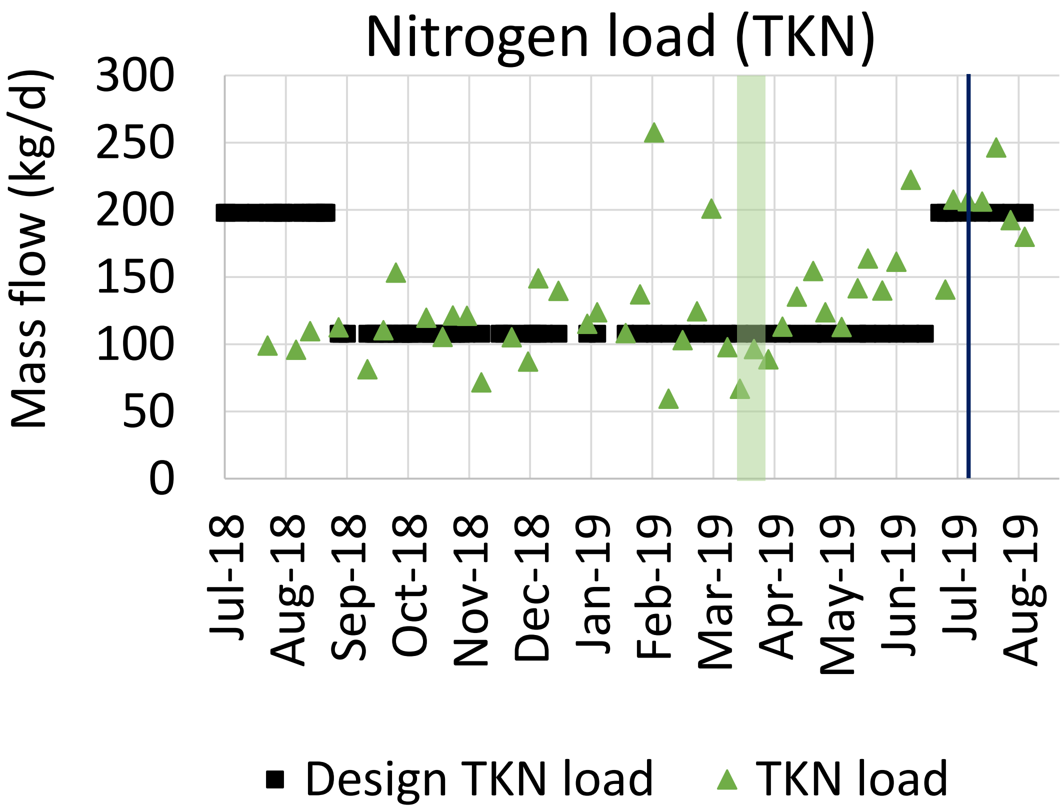
Reactor 2: increase of large granules the whole year

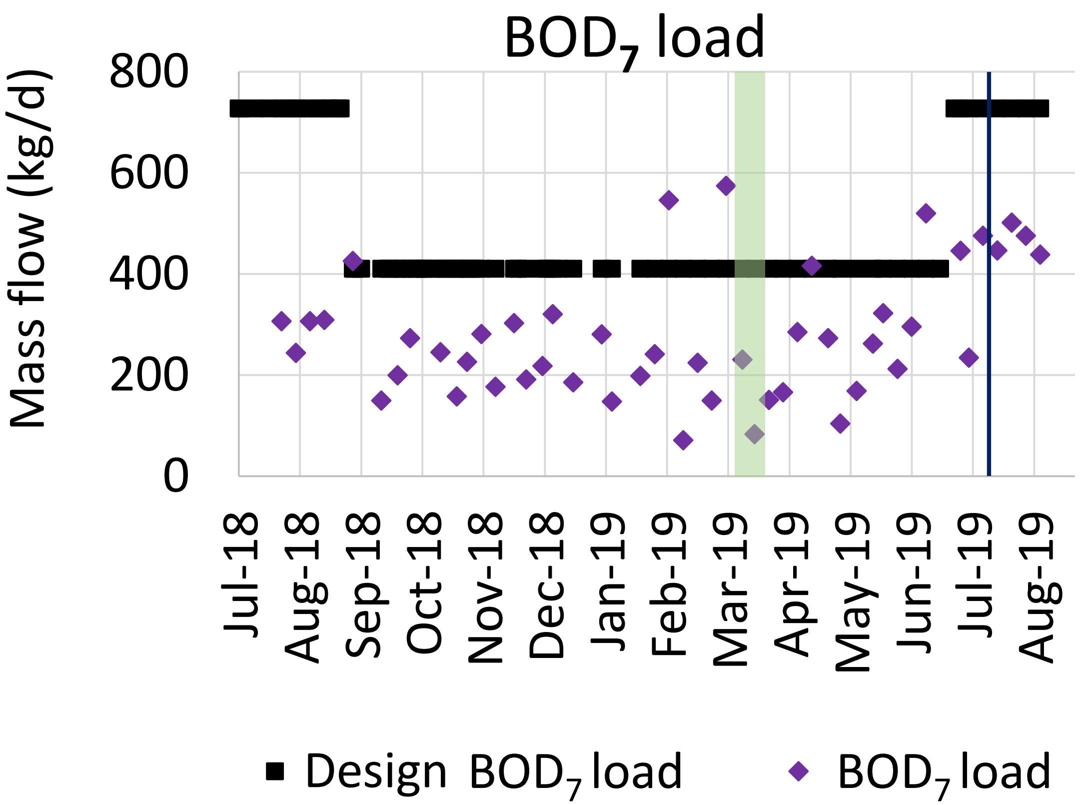


Specific loading COD



Design- and actual load to AGS

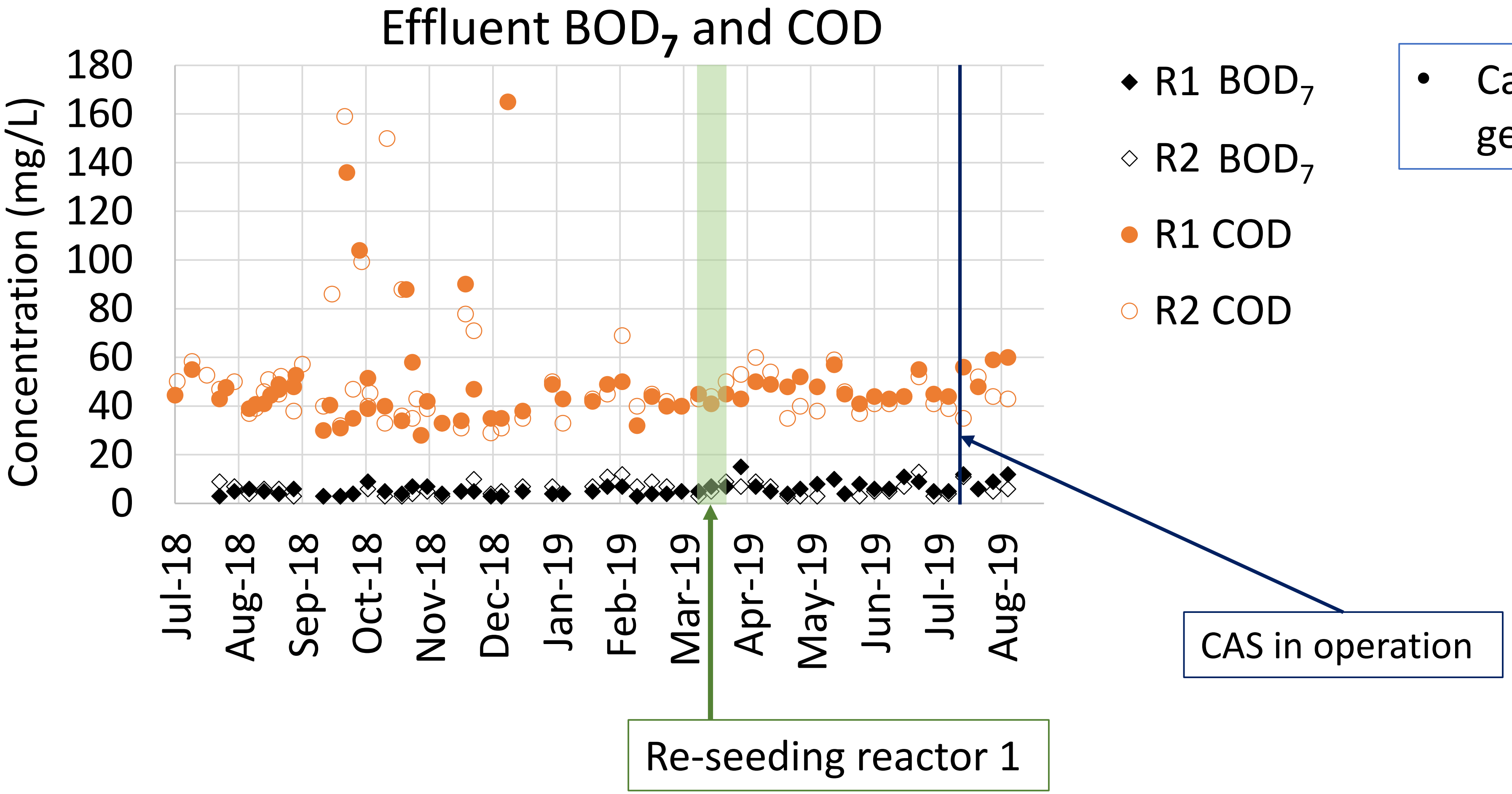




- The actual nitrogen loads were higher than design loads

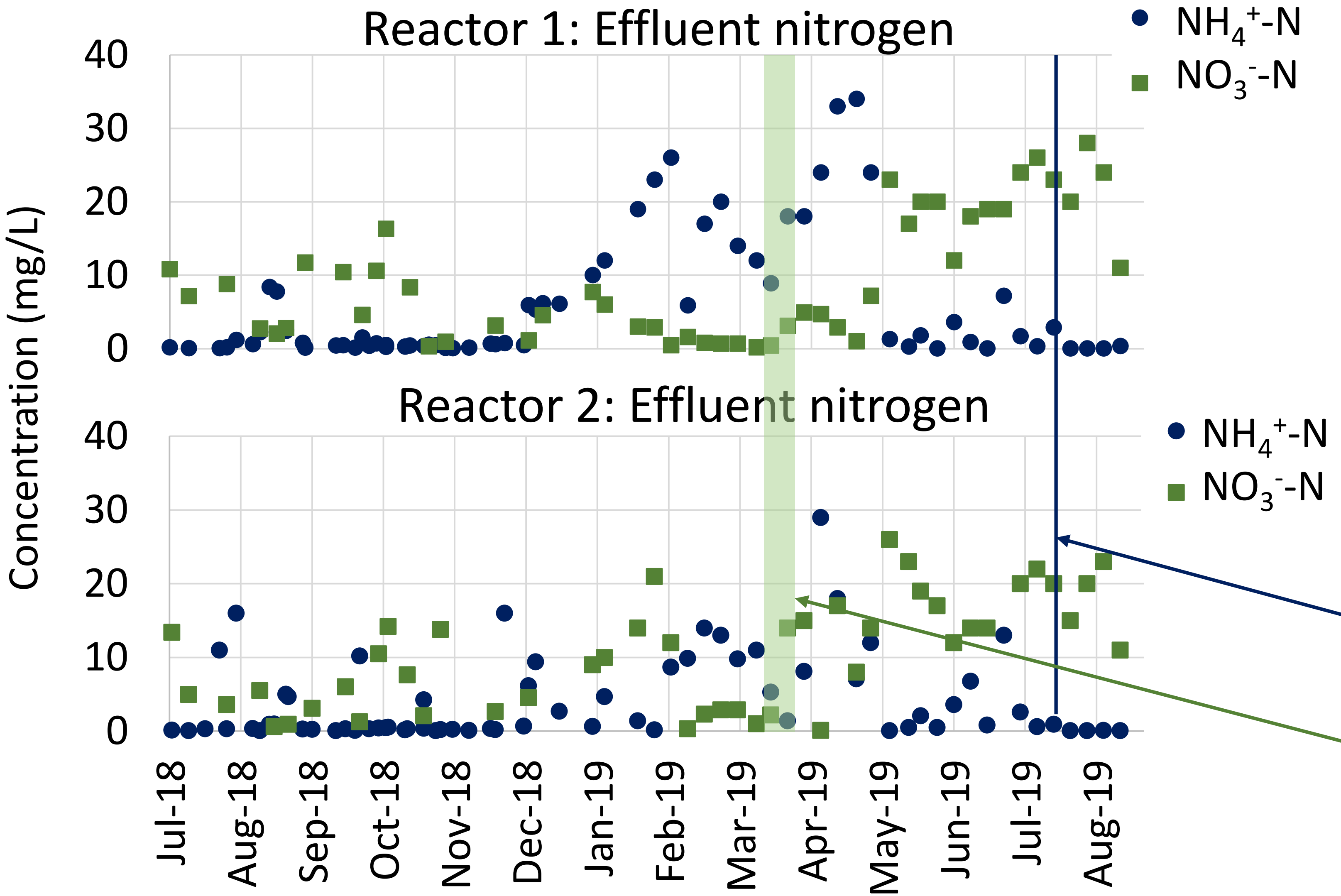
- The actual organic loads were lower than design loads

Results – process performance



- Carbon removal worked generally well

Results – process performance



Decrease in **nitrification**

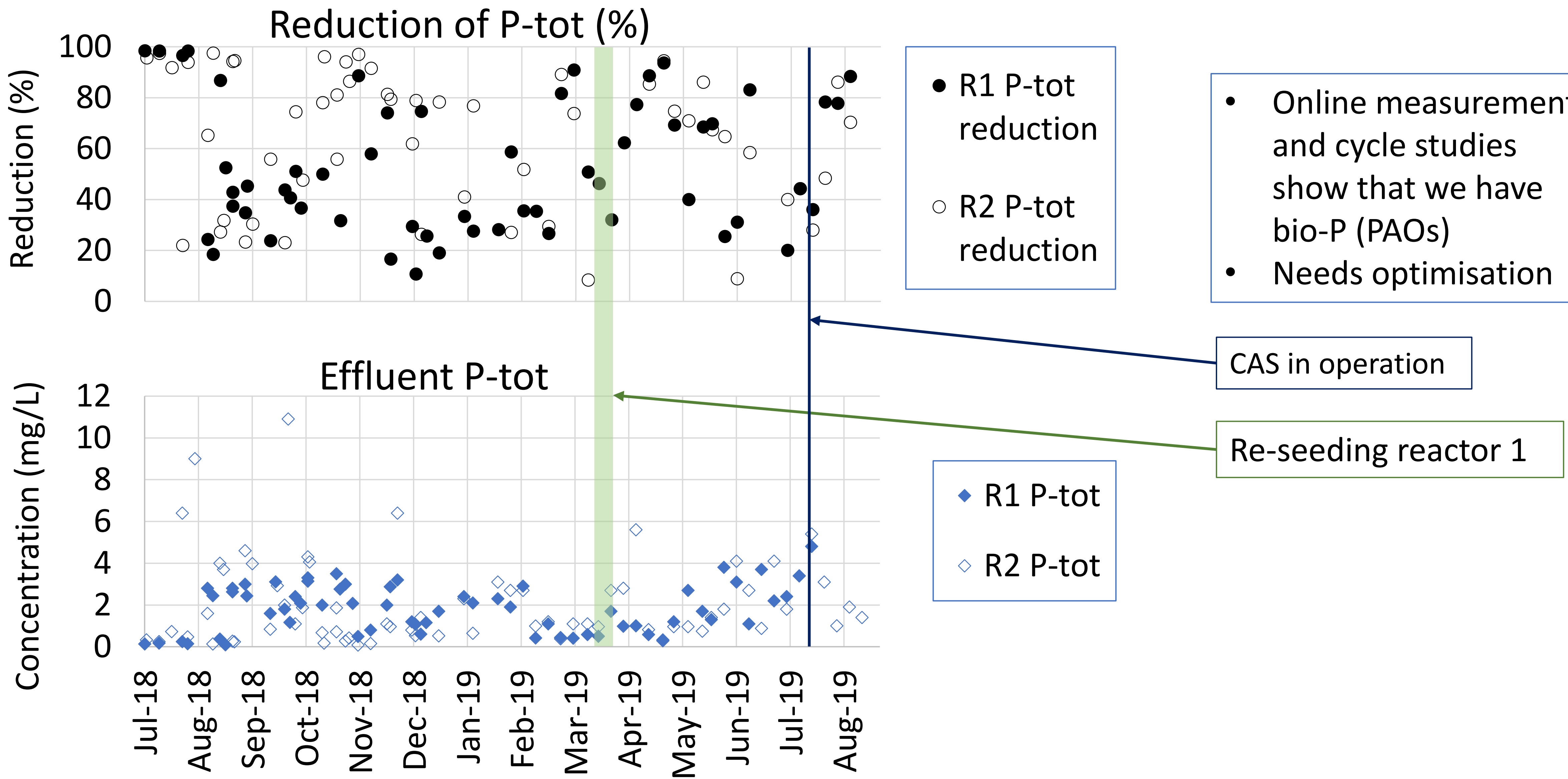
- Short cycle times
- Sludge discharge
- Full load (no CAS)
- Low temperature

➢ Good nitrification summer 2019

Varying **denitrification**

- Low BOD_7/N

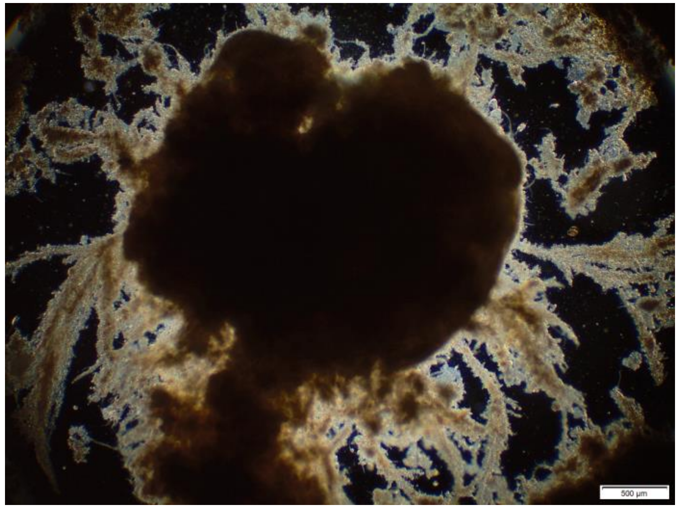
Results – process performance

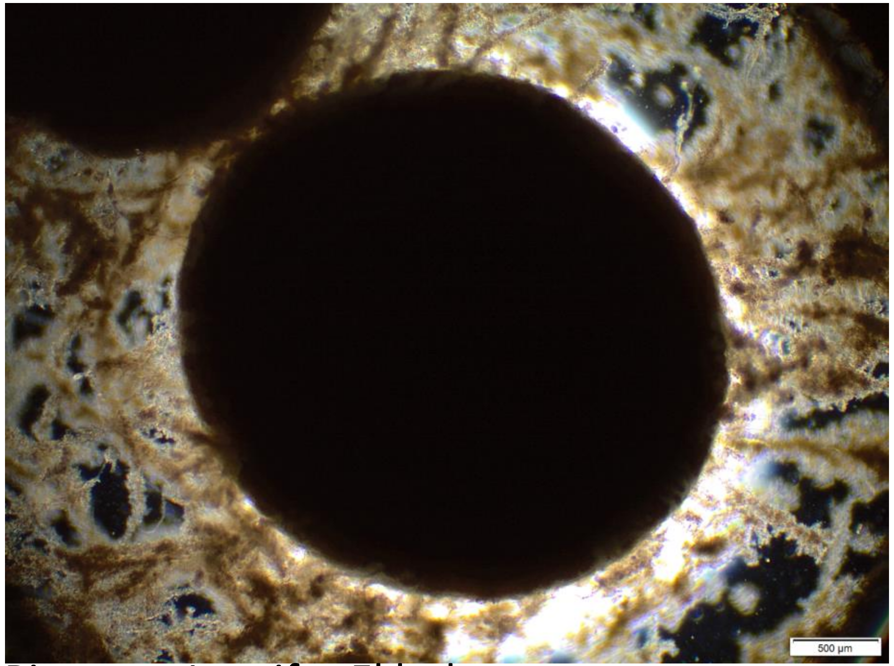


- Online measurement and cycle studies show that we have bio-P (PAOs)
- Needs optimisation

Next

- Hydrolysing primary sludge and by-pass of non-settled water to increase N and P removal
- More data processing
- More activity batch tests
- DNA and FISH analysis
- Temperature study in lab-scale





Pictures: Jennifer Ekholm

1 mm

Conclusions

- The start-up was challenging due to **higher N-loads than design** (reconstruction of CAS) combined with low temperatures.
- **Low BOD_7/N** in AGS influent makes denitrification down to low contents difficult.
- Enhanced bio-P suffers from low VFA- and dissolved COD-contents.
- Nitrification works – but limited nitrification rates combined with high flows (short cycle times) can give challenges during winter.
- Granules with much filamentous outgrowth still had very good SVI and stay in the reactors.
- Good granulation has been achieved in both reactors and in reactor 1 re-seeding was necessary to be able to achieve better treatment results quicker.
- Many technical problems had to be dealt with, such as sludge handling and online instrumentation –> next year is expected to be better.

Thank you for your attention!

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Picture: Britt-Marie Wilén