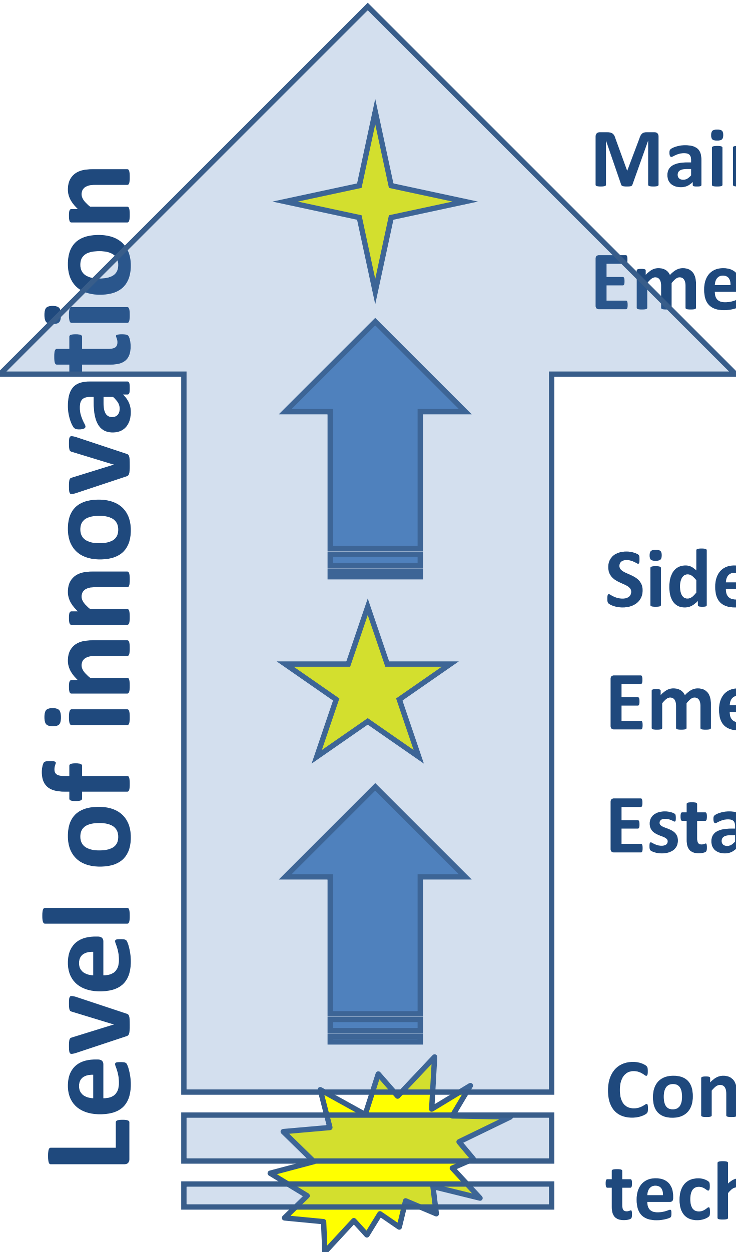
Review of Deammonification projects and key results

Dr. Bernhard Wett

Real world wastewater technologies



Main-stream Deammonification

Emerging technology

Side-stream Deammonification

Emerged technology

Established State of the Art

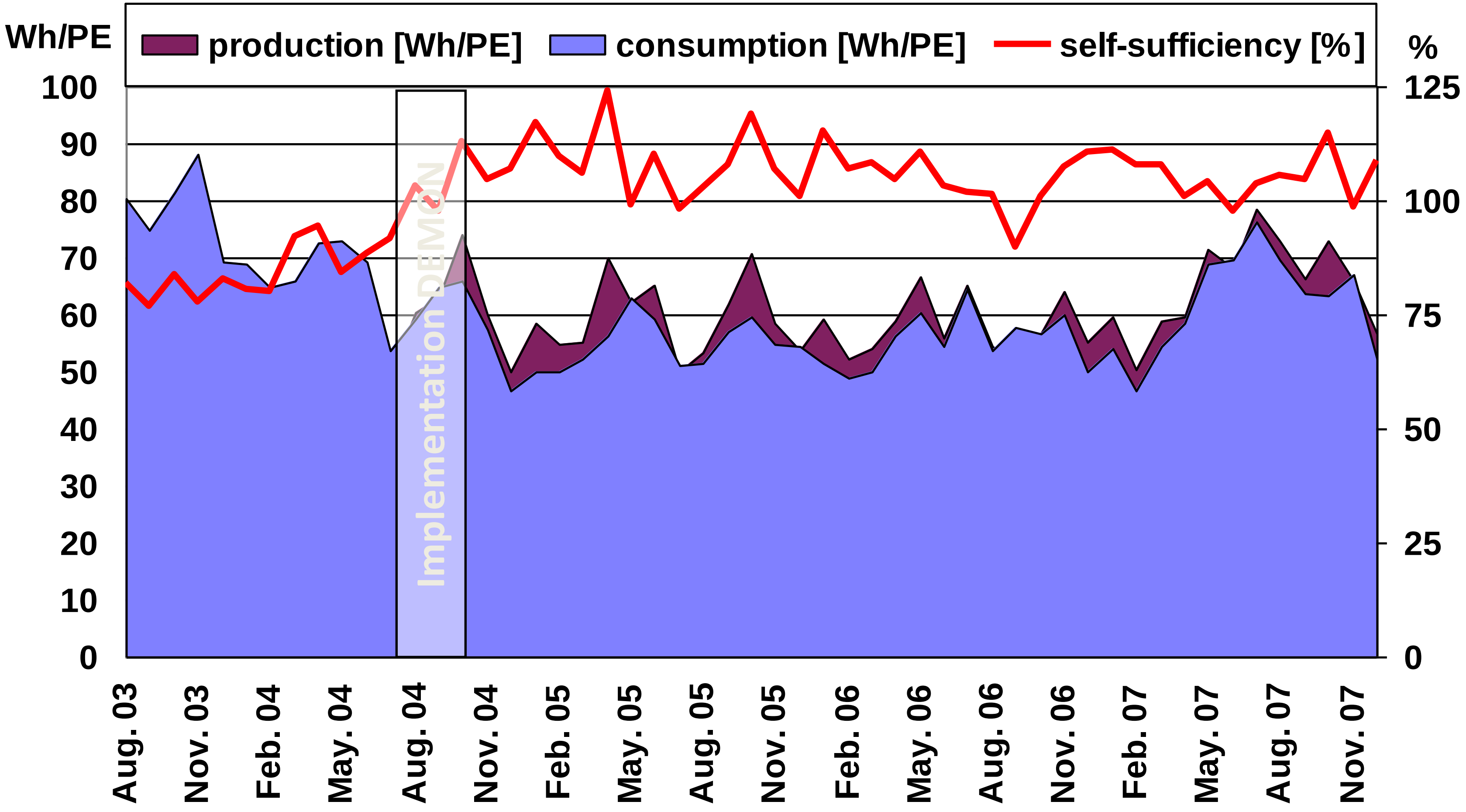
Conventional N-removal technologies

Side-stream applications

DEMON-features –
- **pH-based process control**
- **cyclone for anammox enrichment**

DEMON-implementation –
More than 20 full-scale plants in Europe
(A, Ger, SUI, Hu, NL, Serbia, SF,..)
both municipal and industrial

Incentive - resource savings




Heidelberg / performance test, energy savings

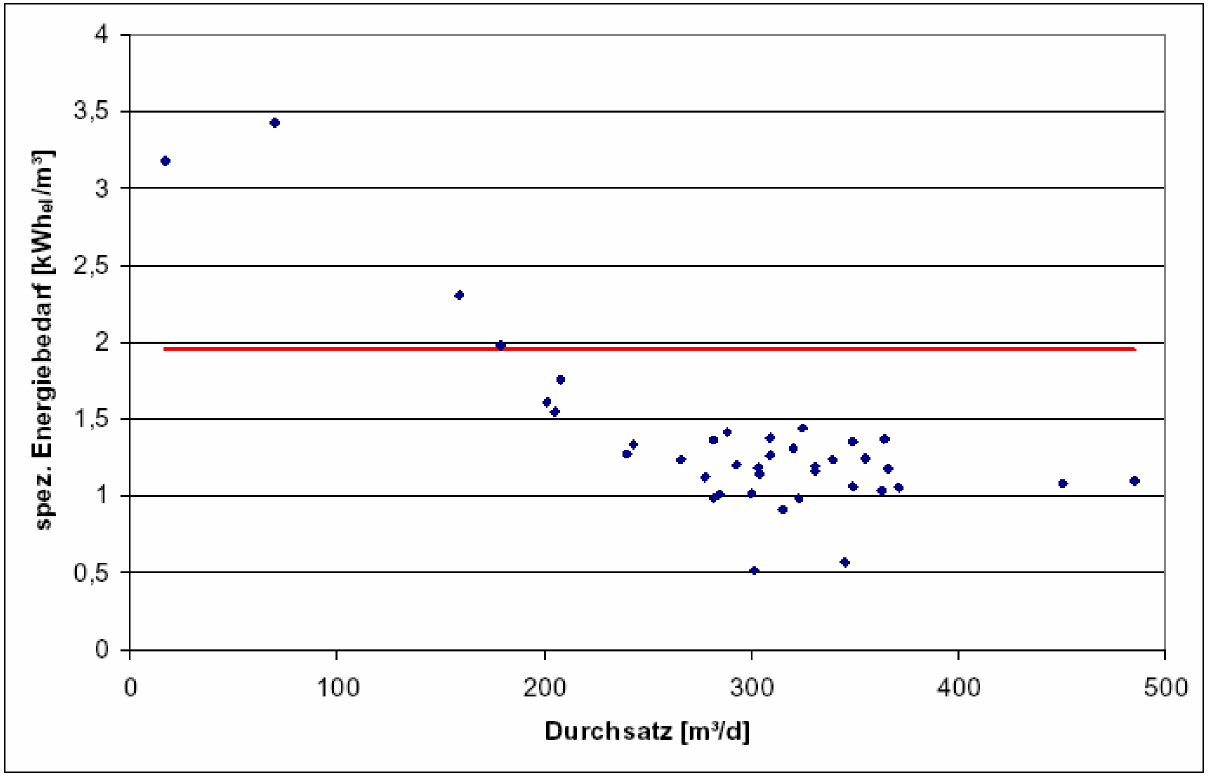
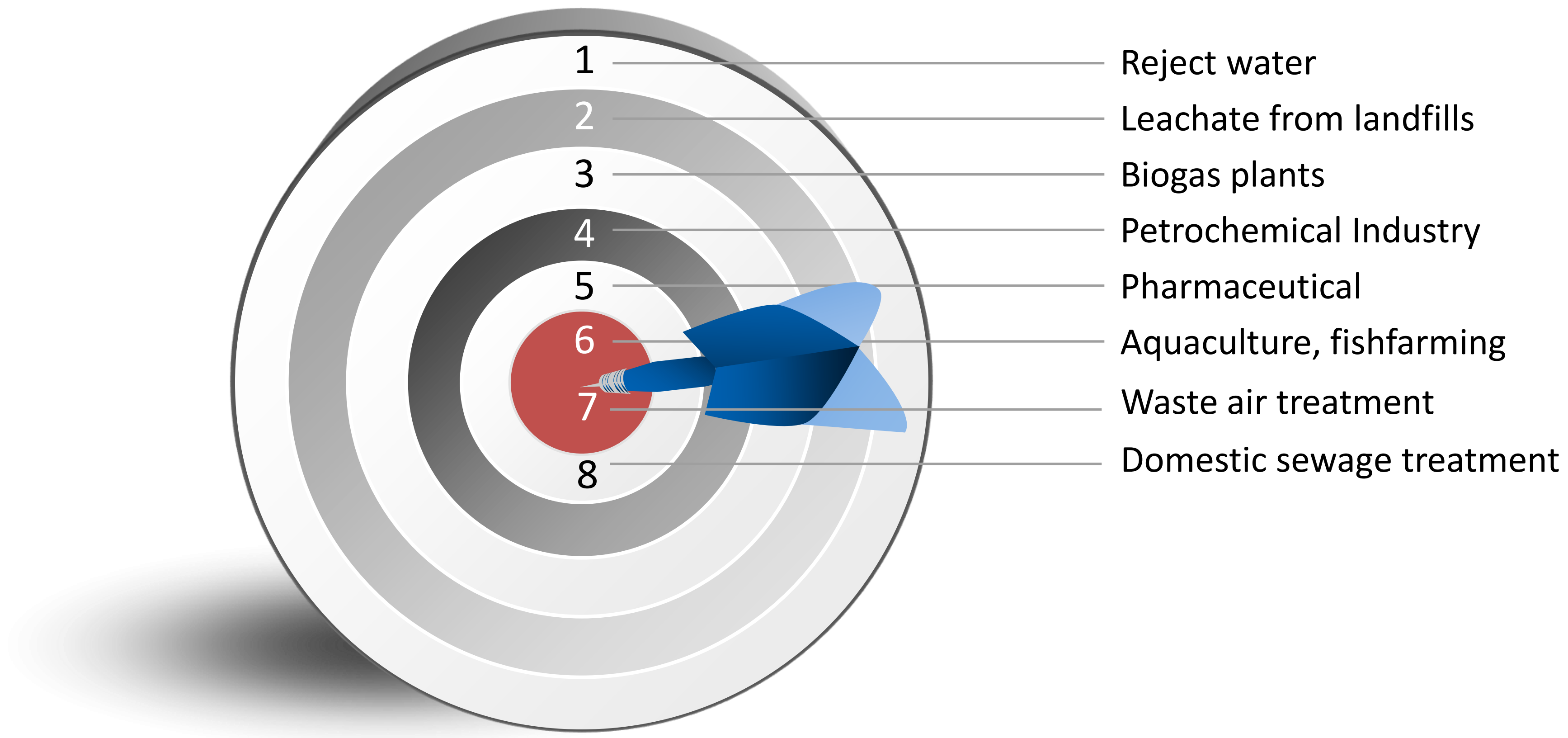


Abbildung 5-2 Elektrischer Energiebedarf durchsatzabhängig ATEMIS

2005 - 2007	2009
3,9 Mio kWh	2,5 Mio kWh
320‘000 pe	270‘000 pe
12,2 kWh/(pe x a)	9,7 kWh/(pe x a)
8,5 % less total energy consumption (per pe)	

applications

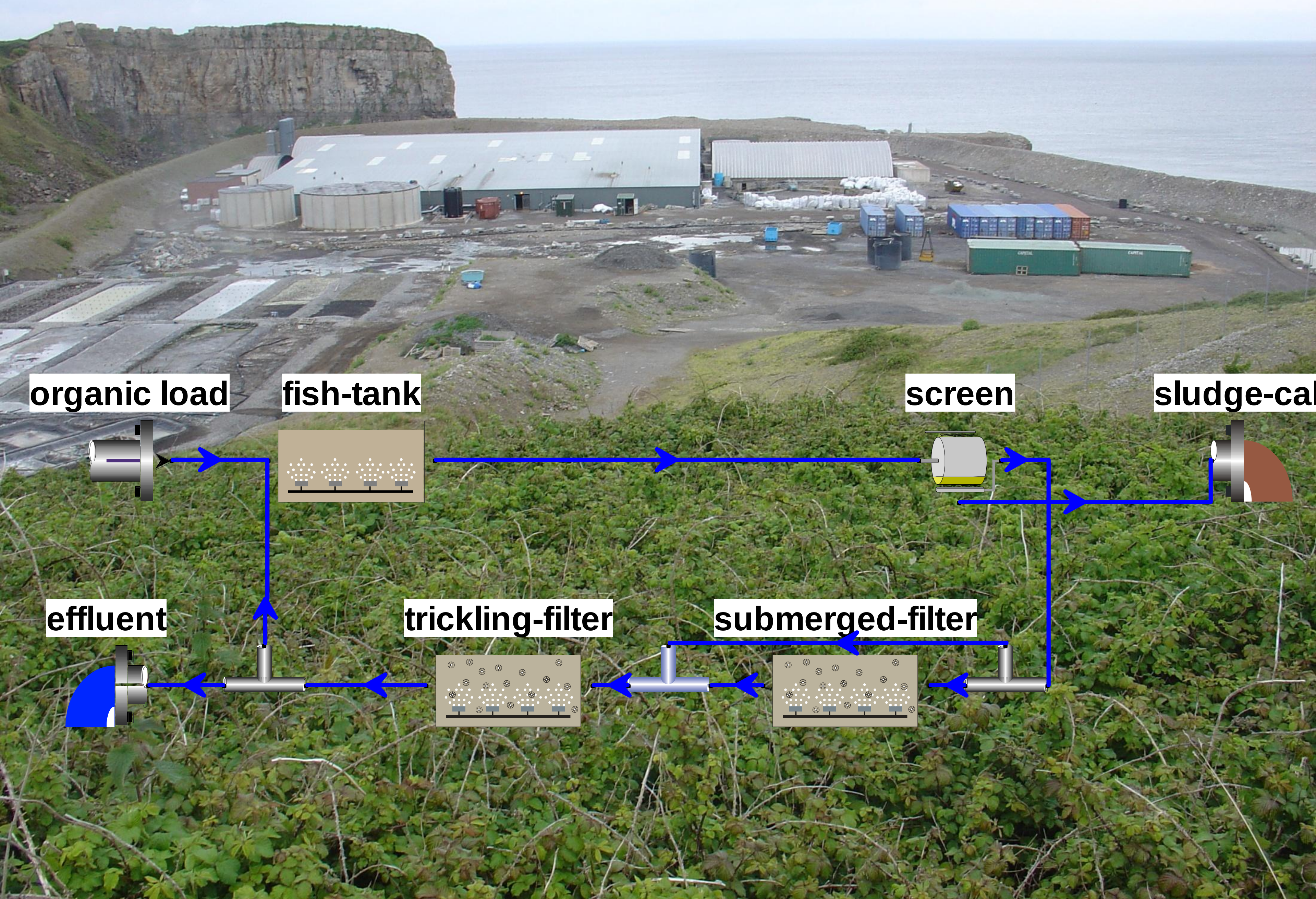


Industrial (2‘400 kg N/d; yeast)

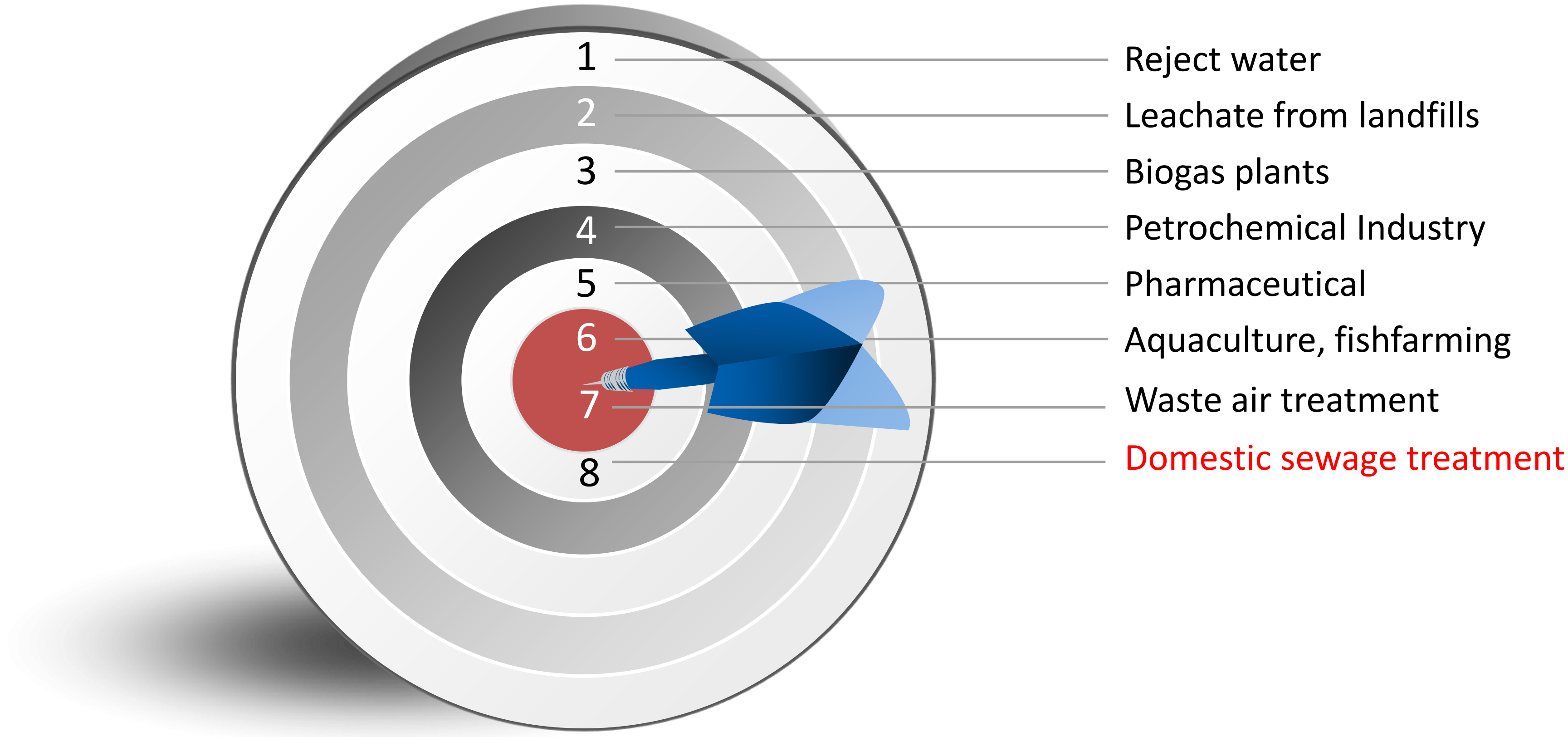
Landfill leachate

Biogas

Aquaculture



applications



WERF-Mainstream Deammonification Project

Objective of full-scale pilots

- **Demonstration** projects at Strass WWTP and Glarnerland WWTP is to demonstrate the feasibility of the deammonification concept, which is already highly successful and proven in sidestream configurations at these plants, for the mainstream process.
- **Using the fundamental process kinetics** and the successful control mechanisms identified for NOB repression and anammox enrichment (Blue Plains bench scale pilots), process modeling was used to help identify the full scale demonstration strategy.
- **Validation and advance the Blue Plains bench scale work**. Data received from the trials will be systematically analyzed by calibration of a numerical model which facilitates understanding of the project results in a generic tool.
- **Ultimately this model will help the design** and implementation of this innovative technology.

WERF-Project-Meeting 15th May 2012

Mainstream Deammonification –

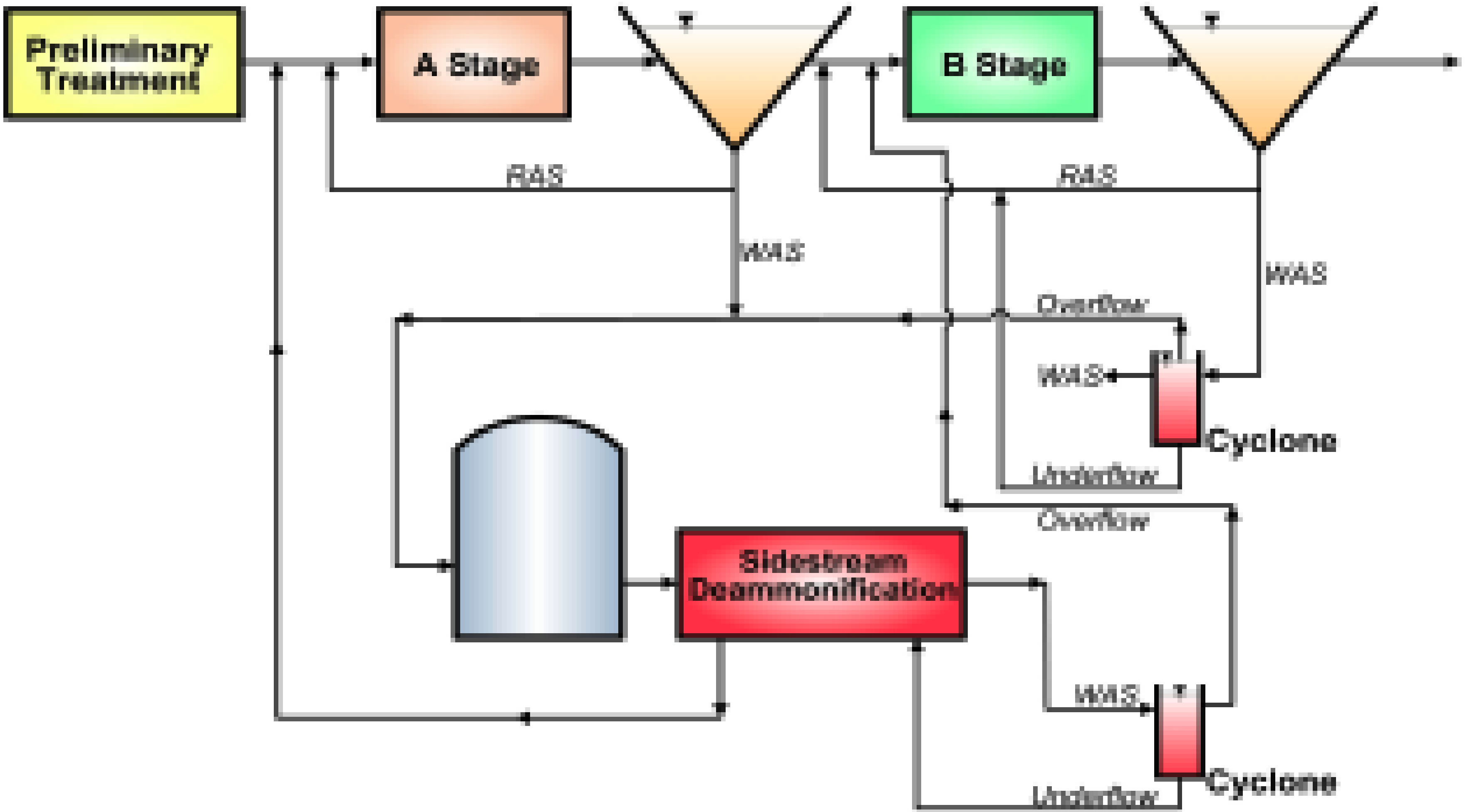
Basic process mechanisms

- Competition for oxygen between AOB and NOB (controlled by DO-level and aeration time and -regimen)
- Competition for nitrite between NOB and Anammox (different nitrite half saturation and temperature sensitivity)

Main process components

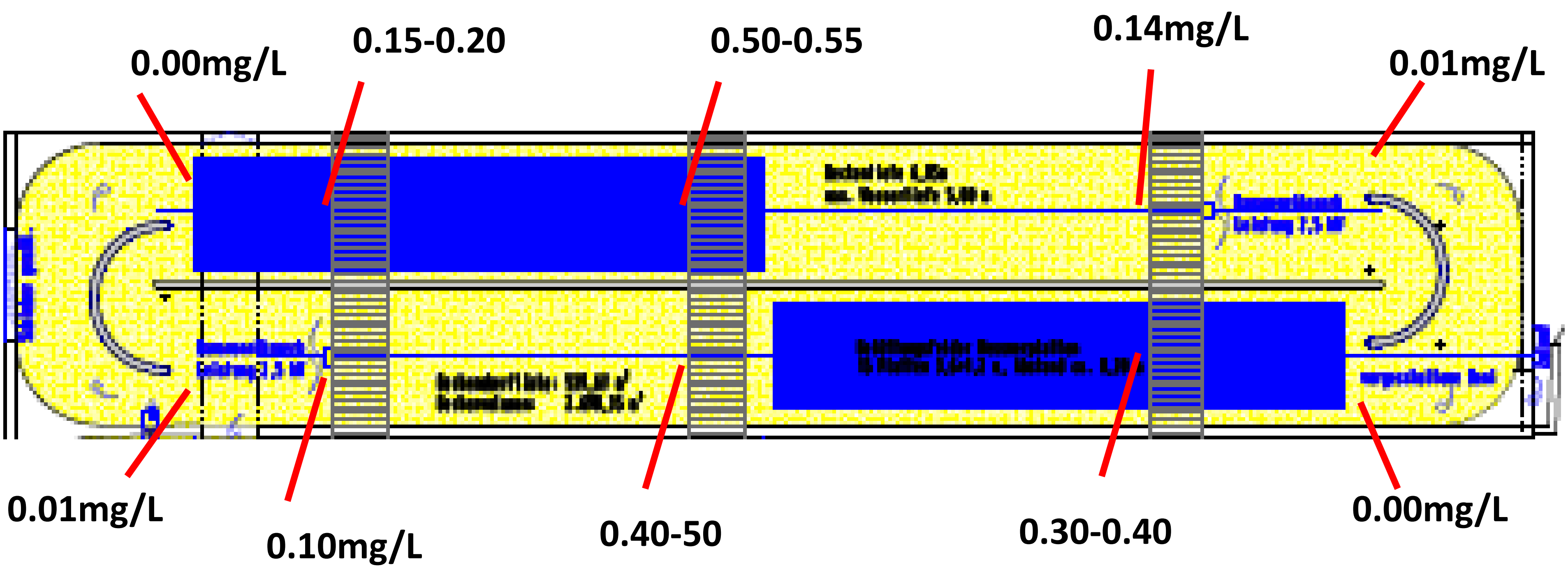
- AOB Bioaugmentation and NOB Repression (Activity Measurements and Ko Determination)
- Anammox Bioaugmentation and Retention Efficiency (Activity Measurements and Particle Tracking)

Operational data Strass



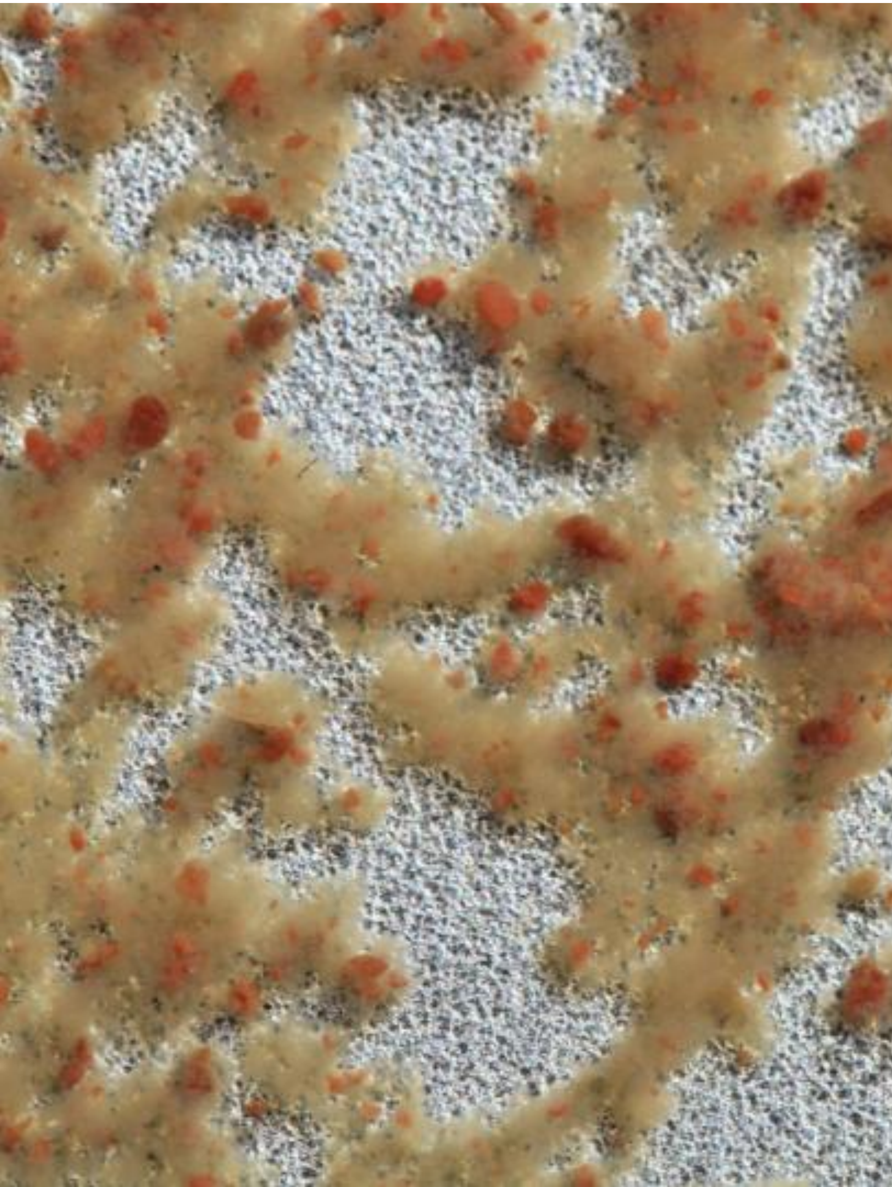
Operational modes and -phases at the Strass pilot

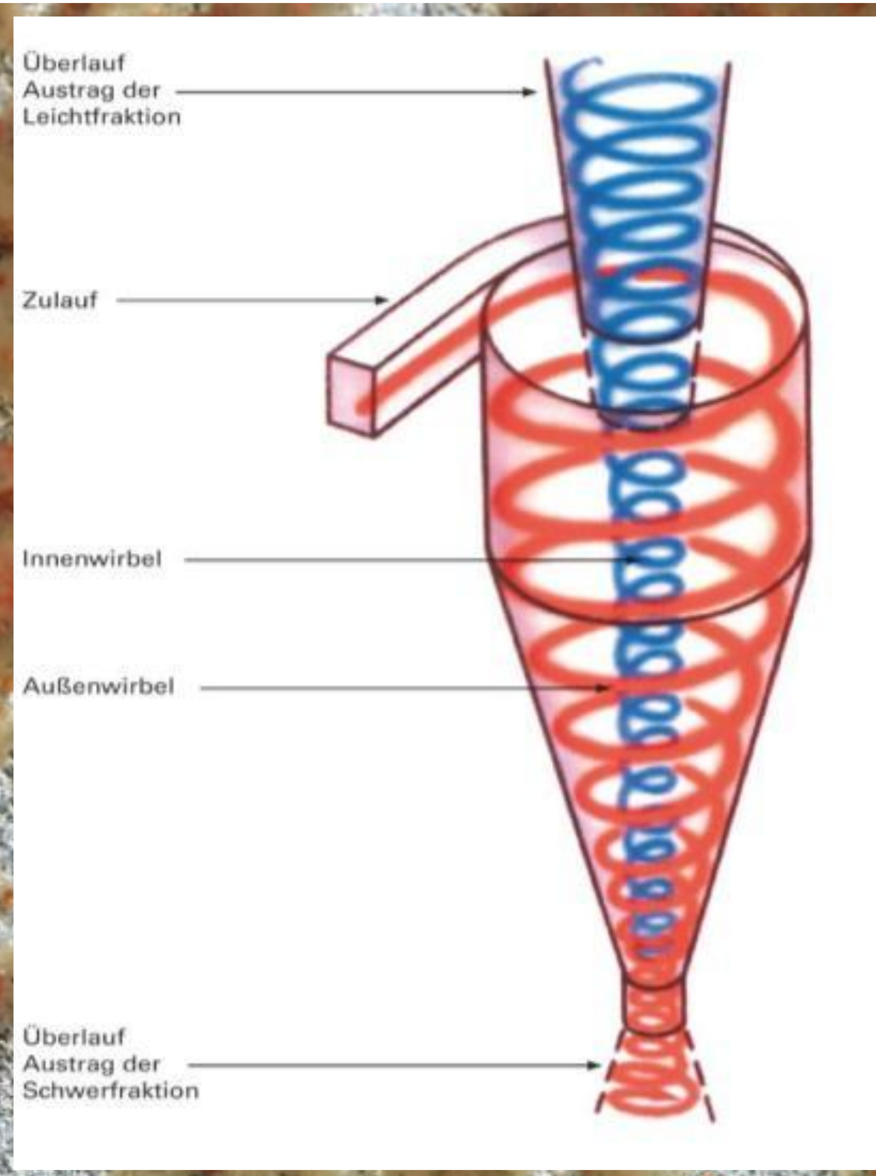
cyclone set-up	date	operation mode and DO set-points in tanks T1 and T2
no cyclone	before June	serial tanks; MLE-mode; T1 swing and T2=2.0
batteries of small high-pressure cyclones	01.06.2011	
	06.06.2011	parallel tanks; T1=0.7 and T2=0.7
	18.08.2011	serial tanks; T1=0.5 and T2=0.7
2 large low-pressure cyclones	06.09.2011	
	29.09.2011	serial tanks; T1=0.9 and T2=0.4
	28.11.2011	serial tanks; MLE-mode; T1 swing and T2=2.0
	31.01.2012	

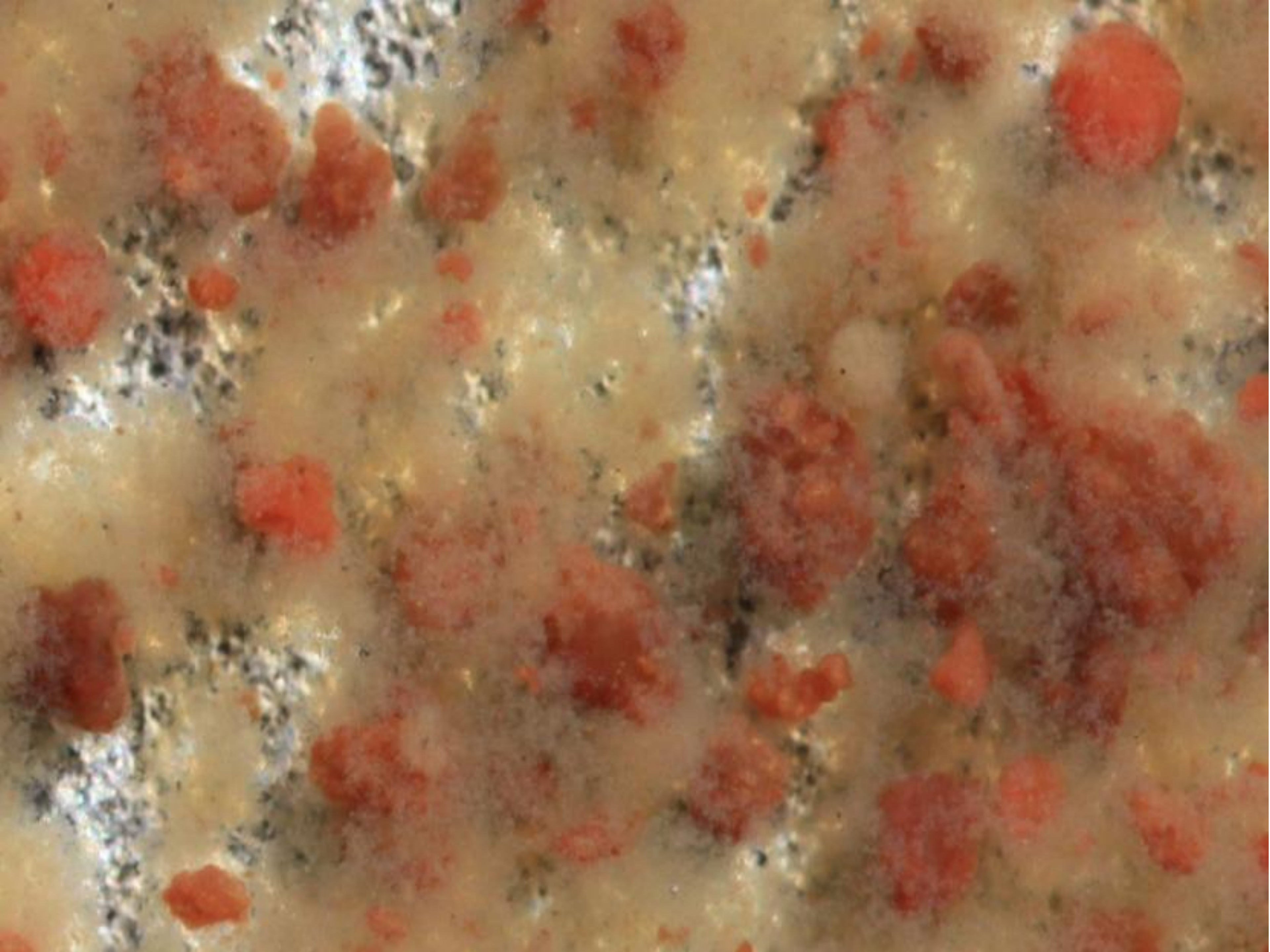


Hydro-cyclones

Purpose – to seperate flocs (mainly AOB) and granules (mainly AMX) in order to select for different SRTs

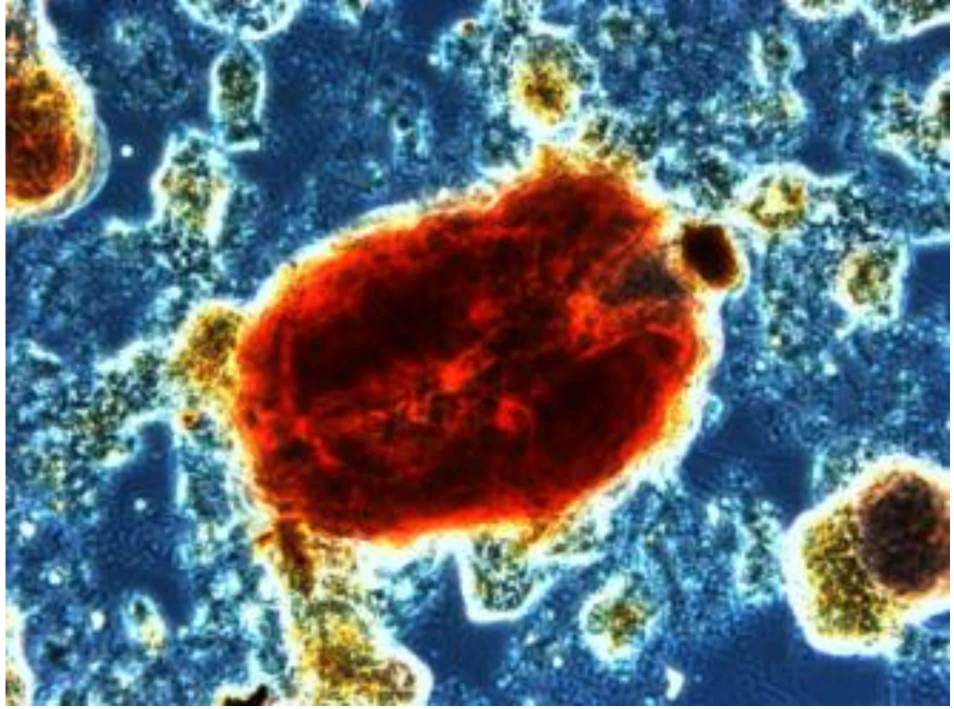


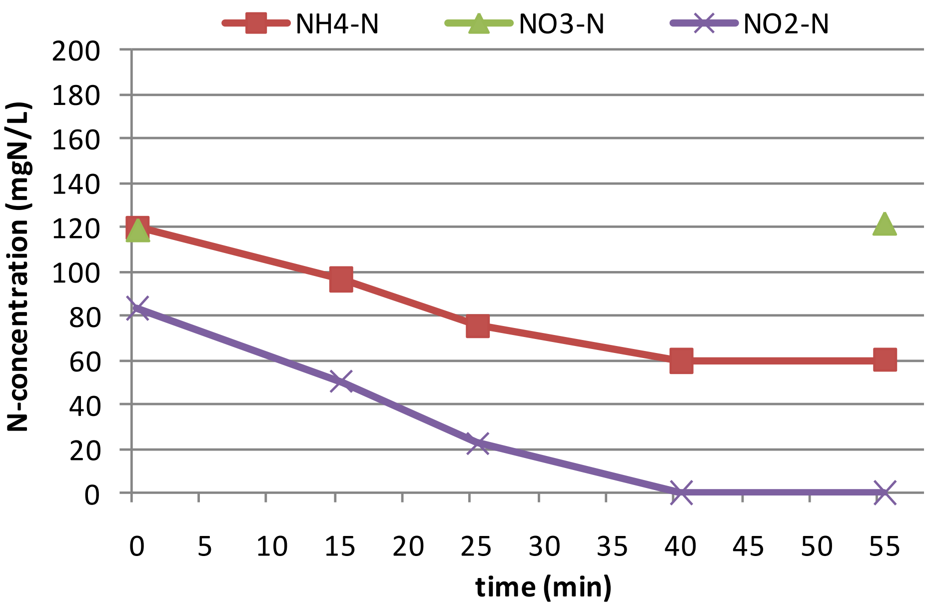


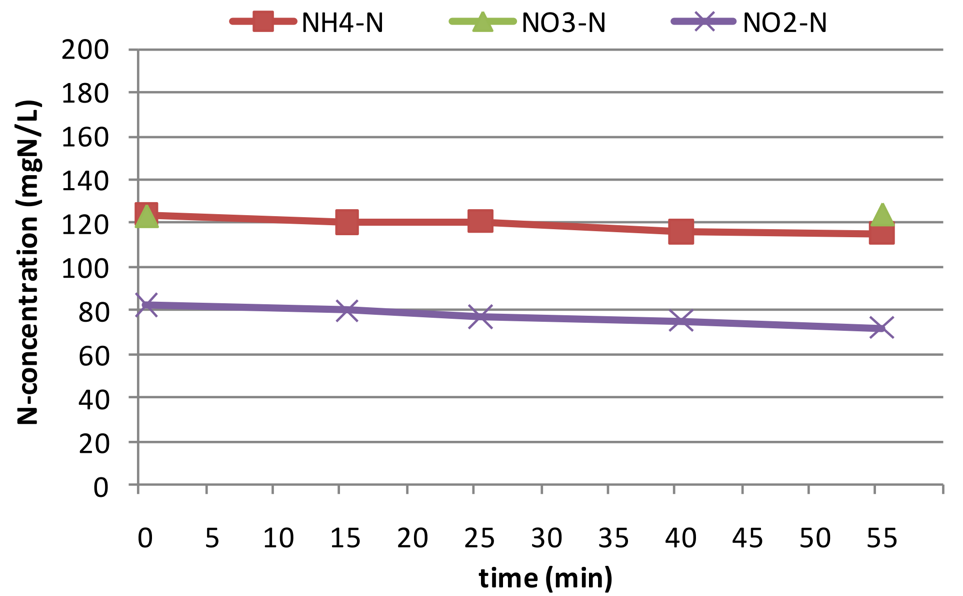


Cyclone sizing and configuration

Medium size Q=10m3/h per cyclon

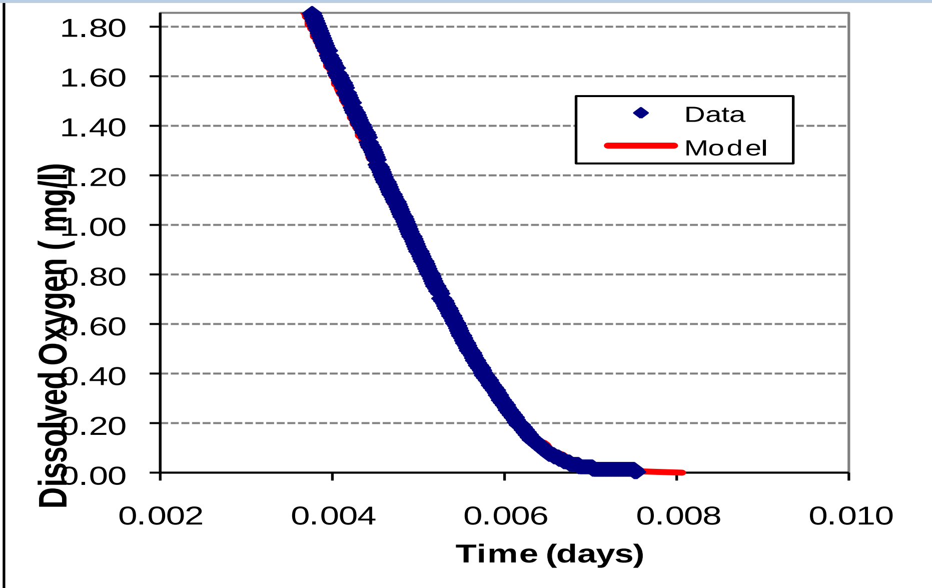


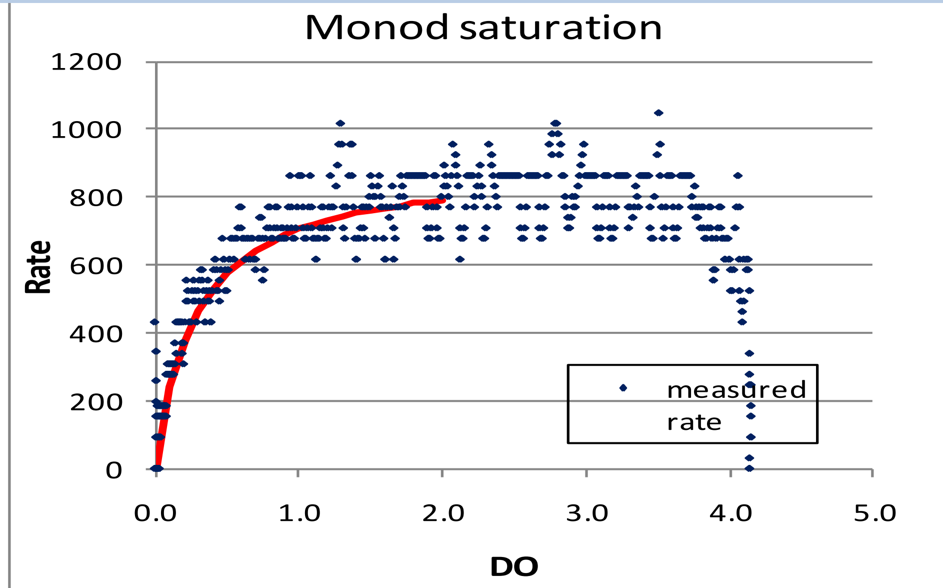


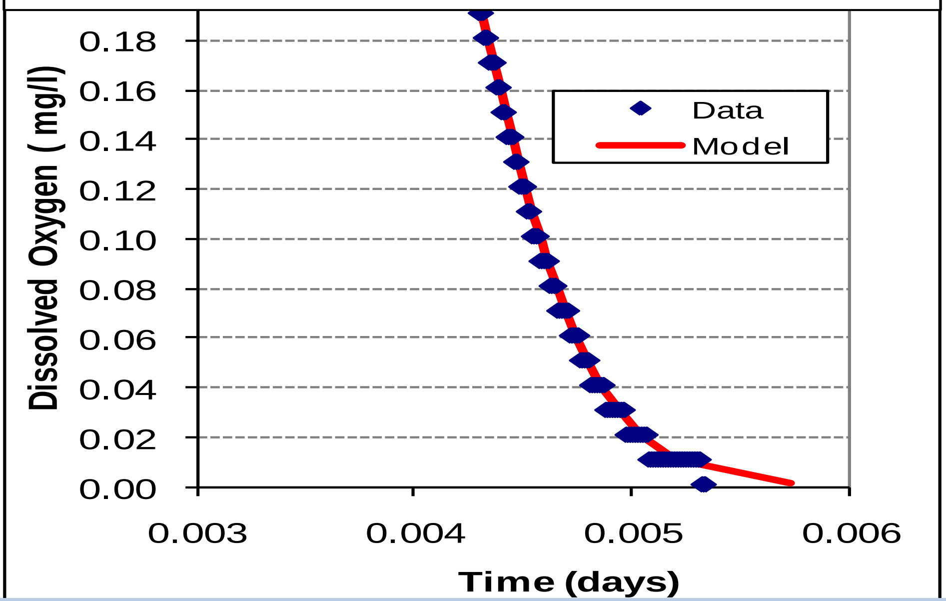


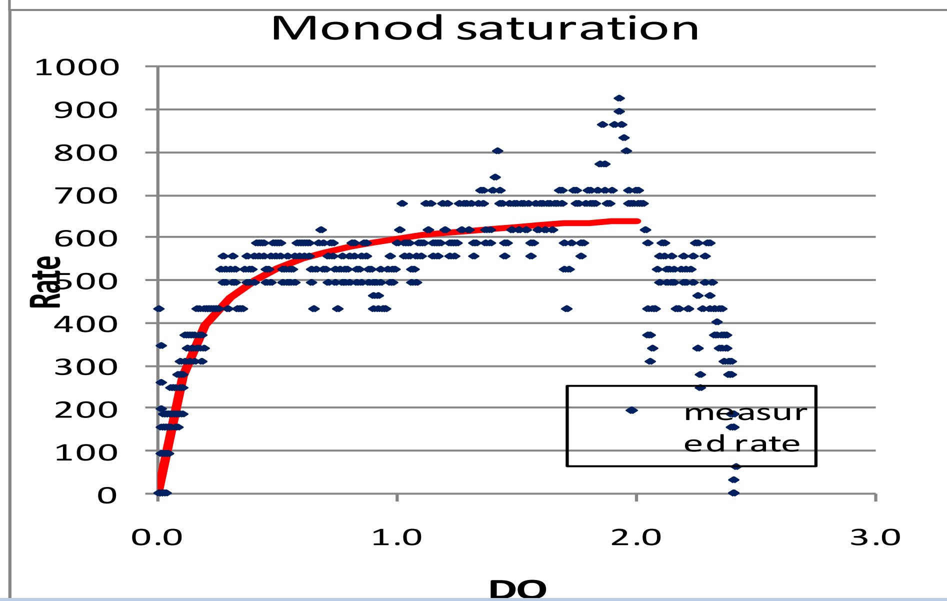
cyclone under-flow (recycled) and overflow (wasted)

Spread-sheet models for systematic analyses of declining DO-tests



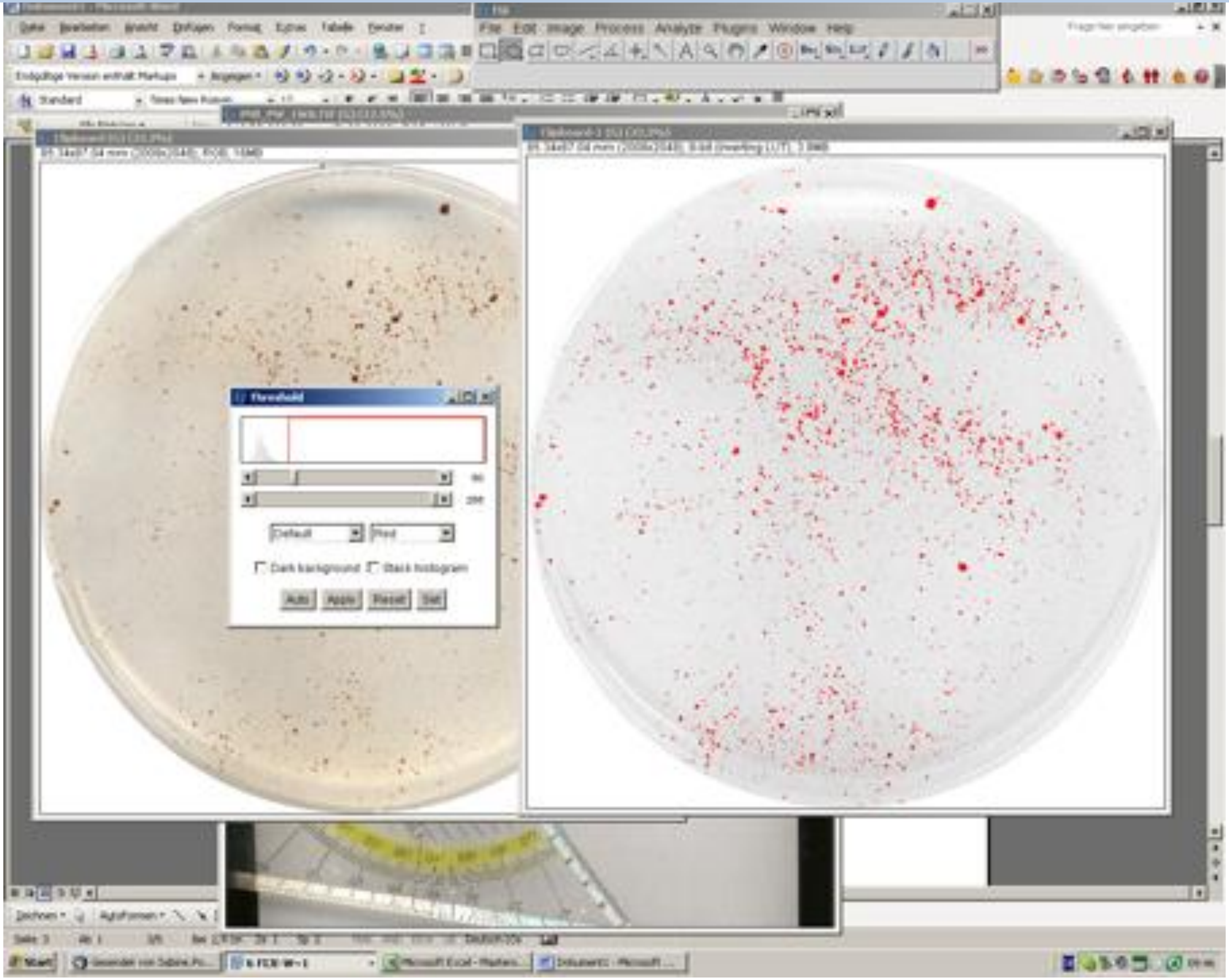




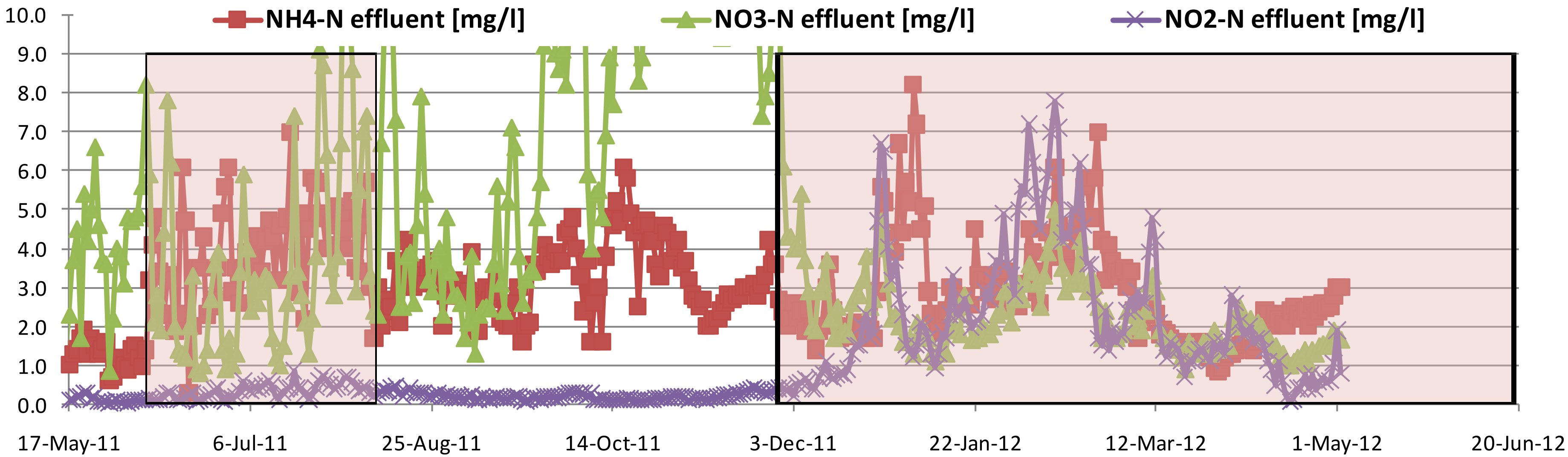


Calibration of maximum growth-rates (linear range of depletion profile) and DO half saturation coefficients (curvature of profiles)

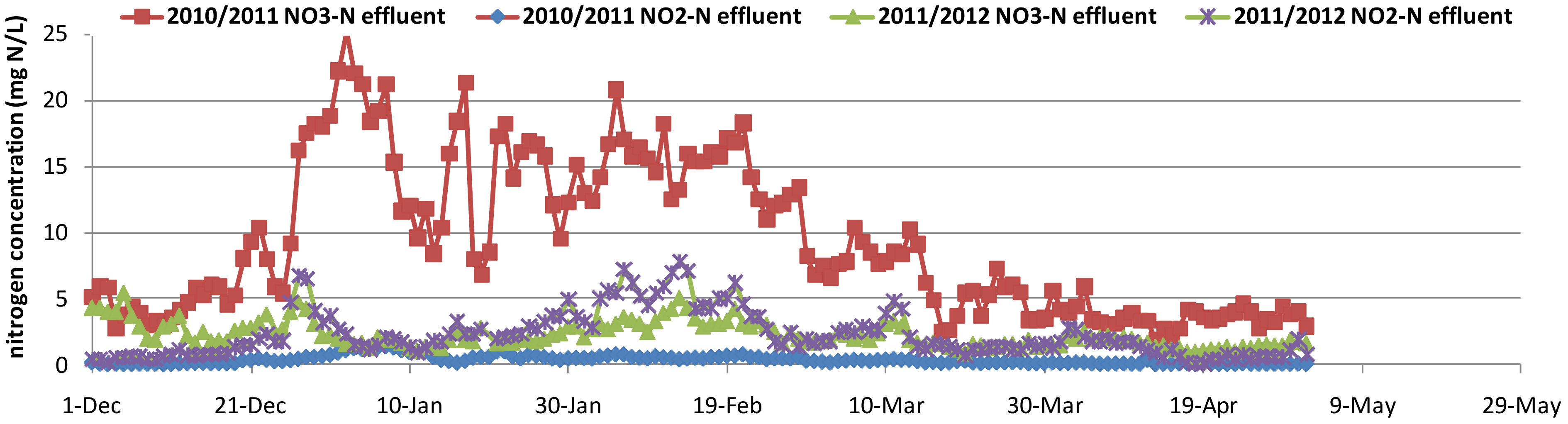
Image analyses based on particle size calculation color filtration



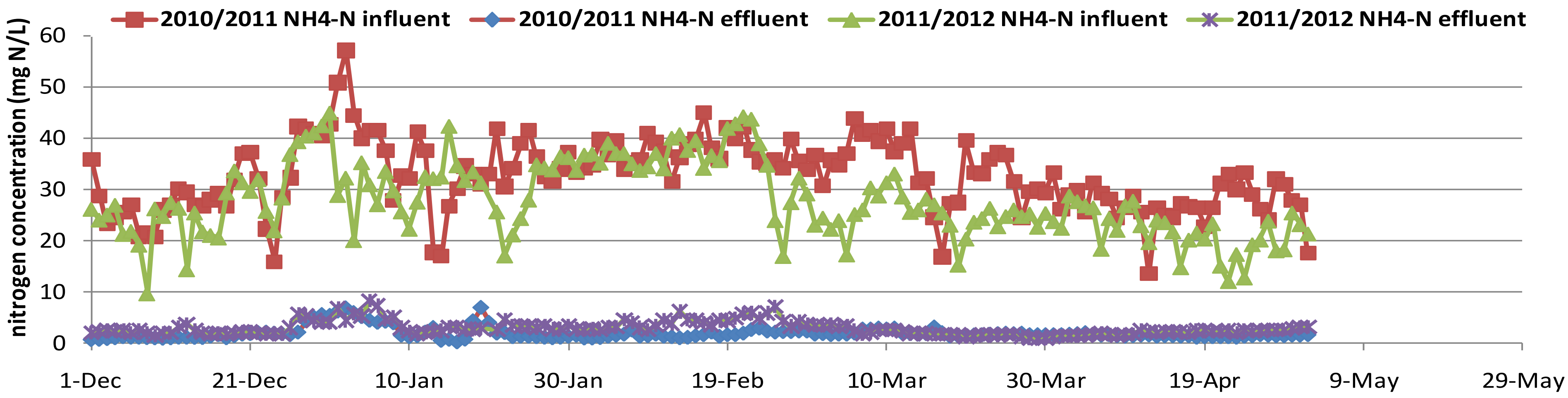
Allows particle number counts, prticle size distribution and estimation of total volume or mass of anammox granules, respectively

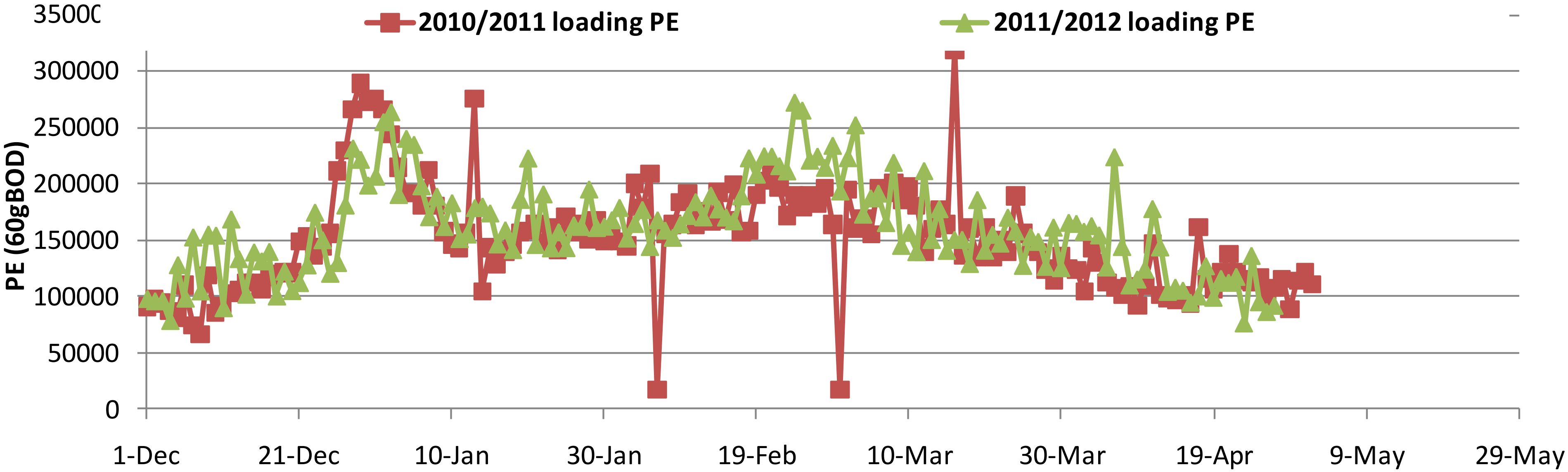


two most successful operation modes for NOB-repression (SND-type low DO and MLE-type high DO)

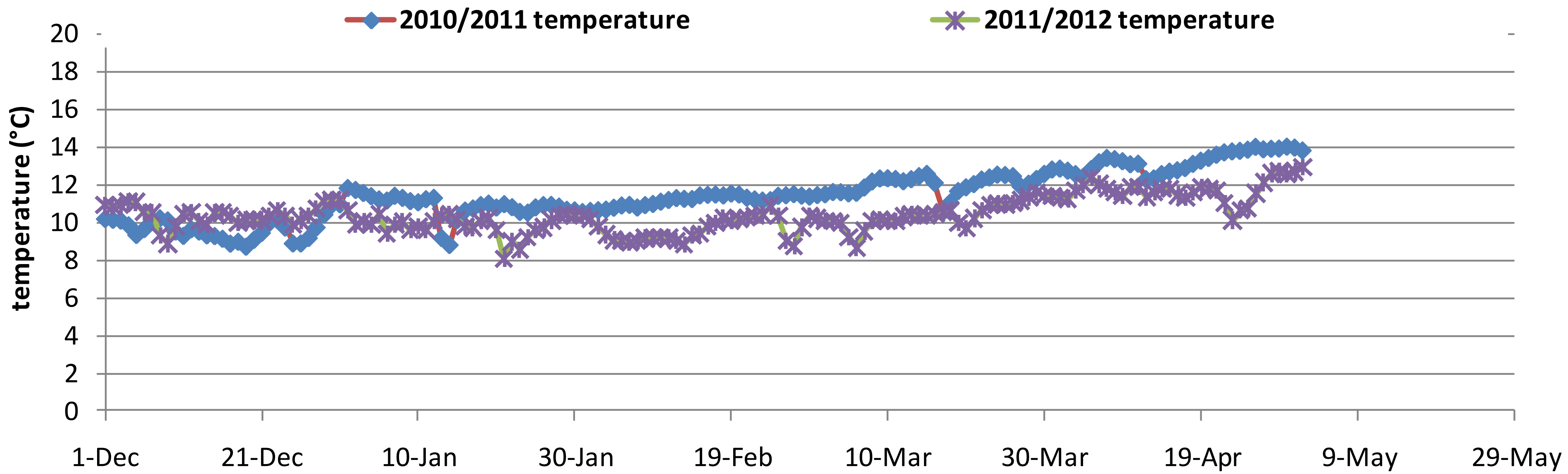


Comparison of this year's and last year's operational data of the full-scale pilot Strass indicating advanced NOB-repression (typically high nitrate level at Christmas peak-load; similar temperature conditions of ca. 10°C , load conditions and ammonia effluent concentrations of ca. 2-5 mgN/L for both years)

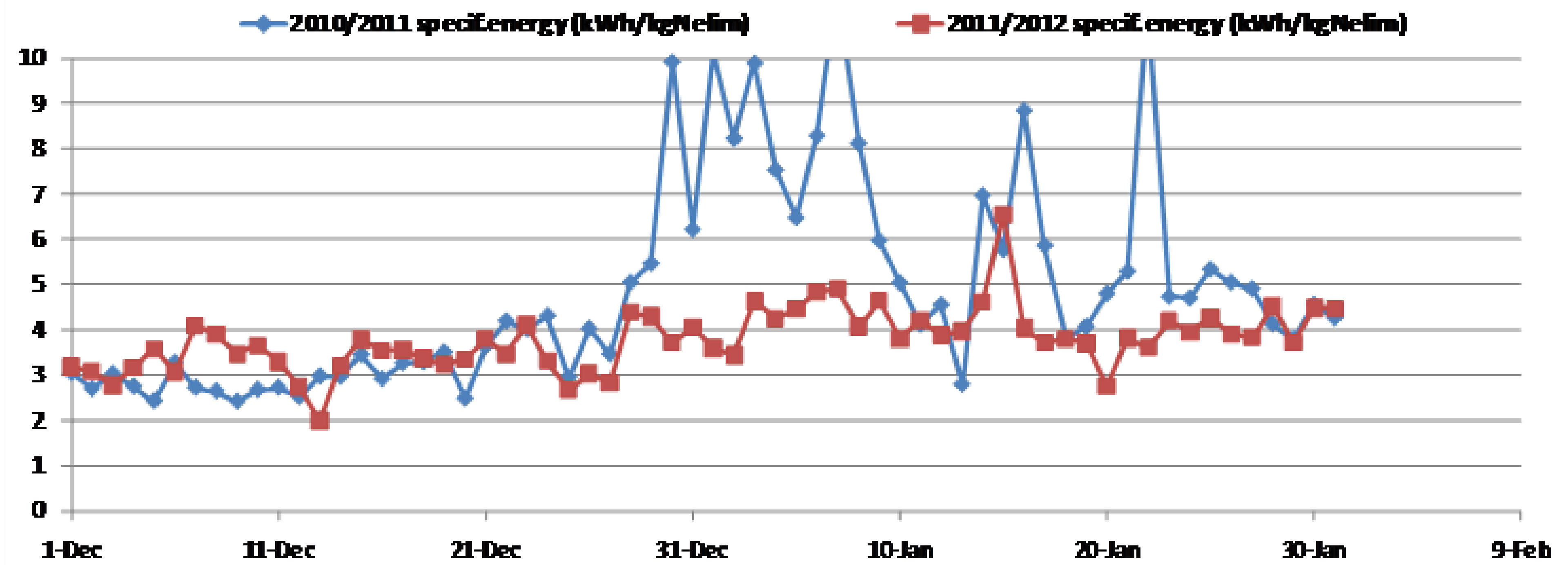




Plant loading profiles (PE) and MLSS (TSS).

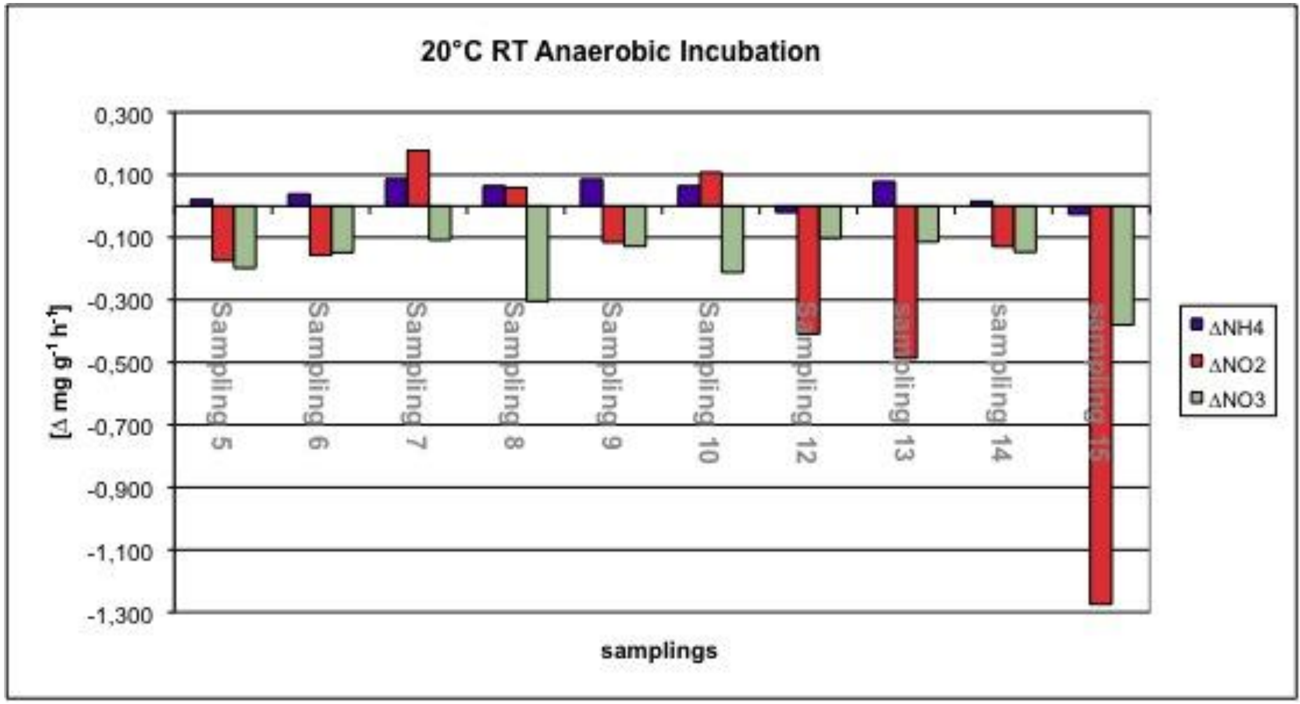


SVI-profiles (ml/g) and temperature (°C)

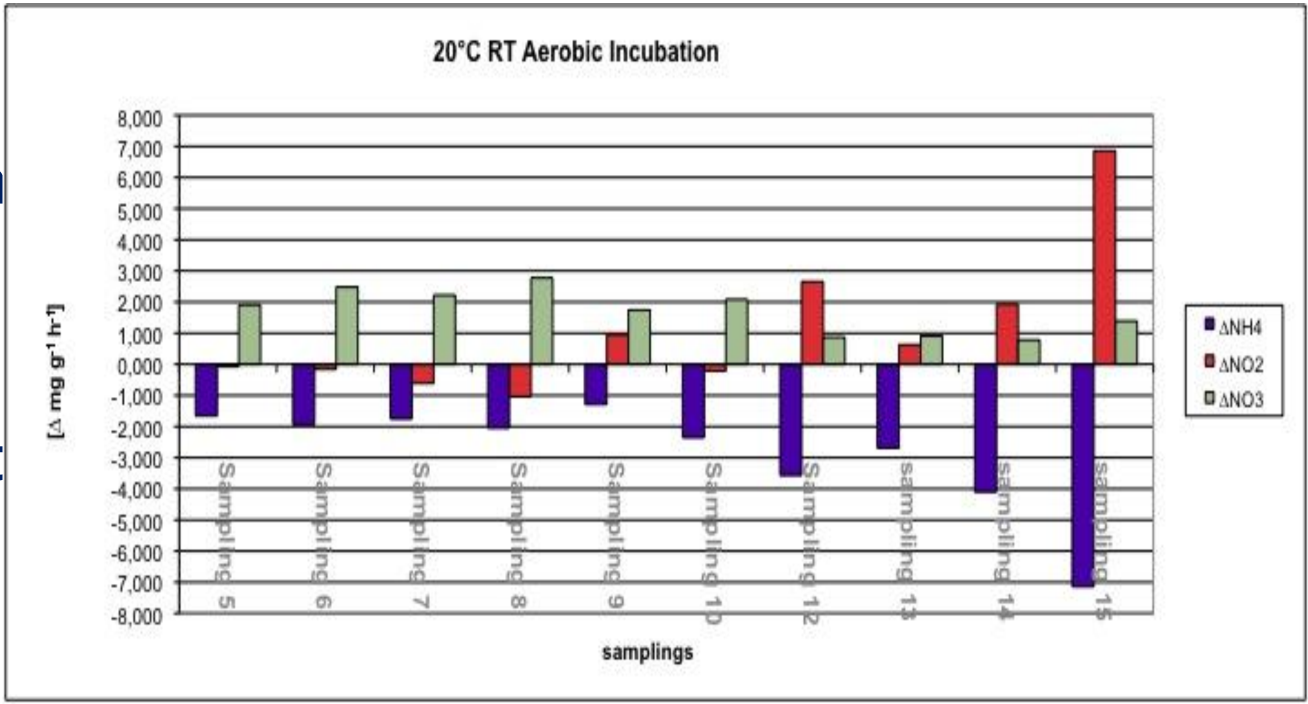


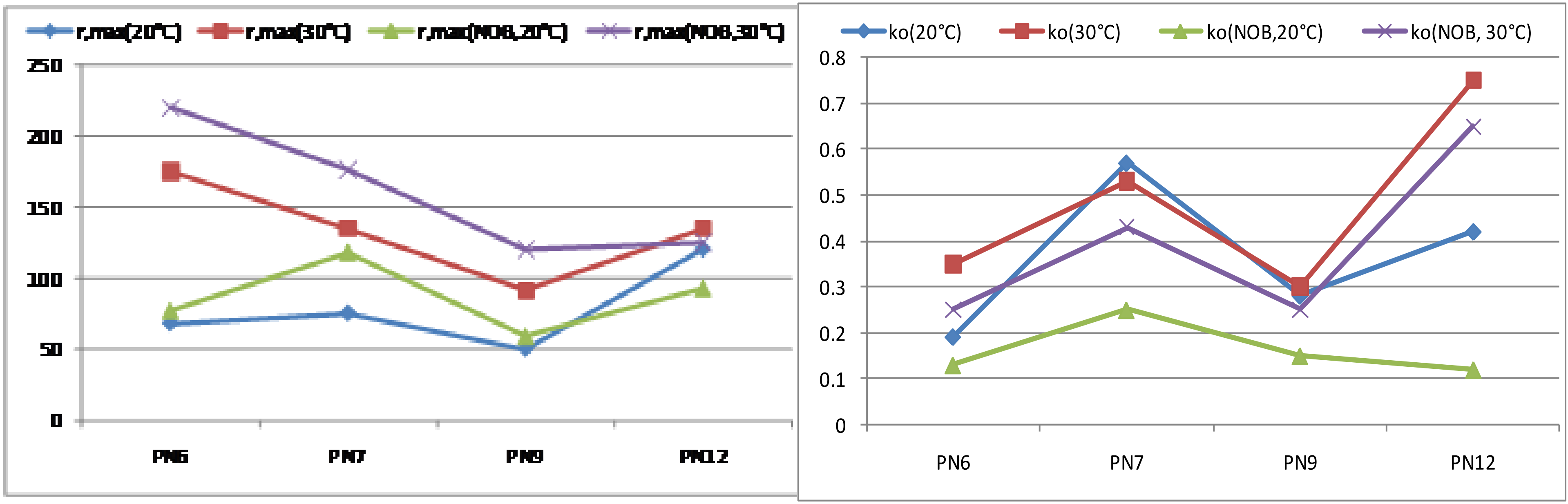
Specific energy demand for nitrogen removal

The last samples show ammonia removal during anaerobic activity test (anammox activity)

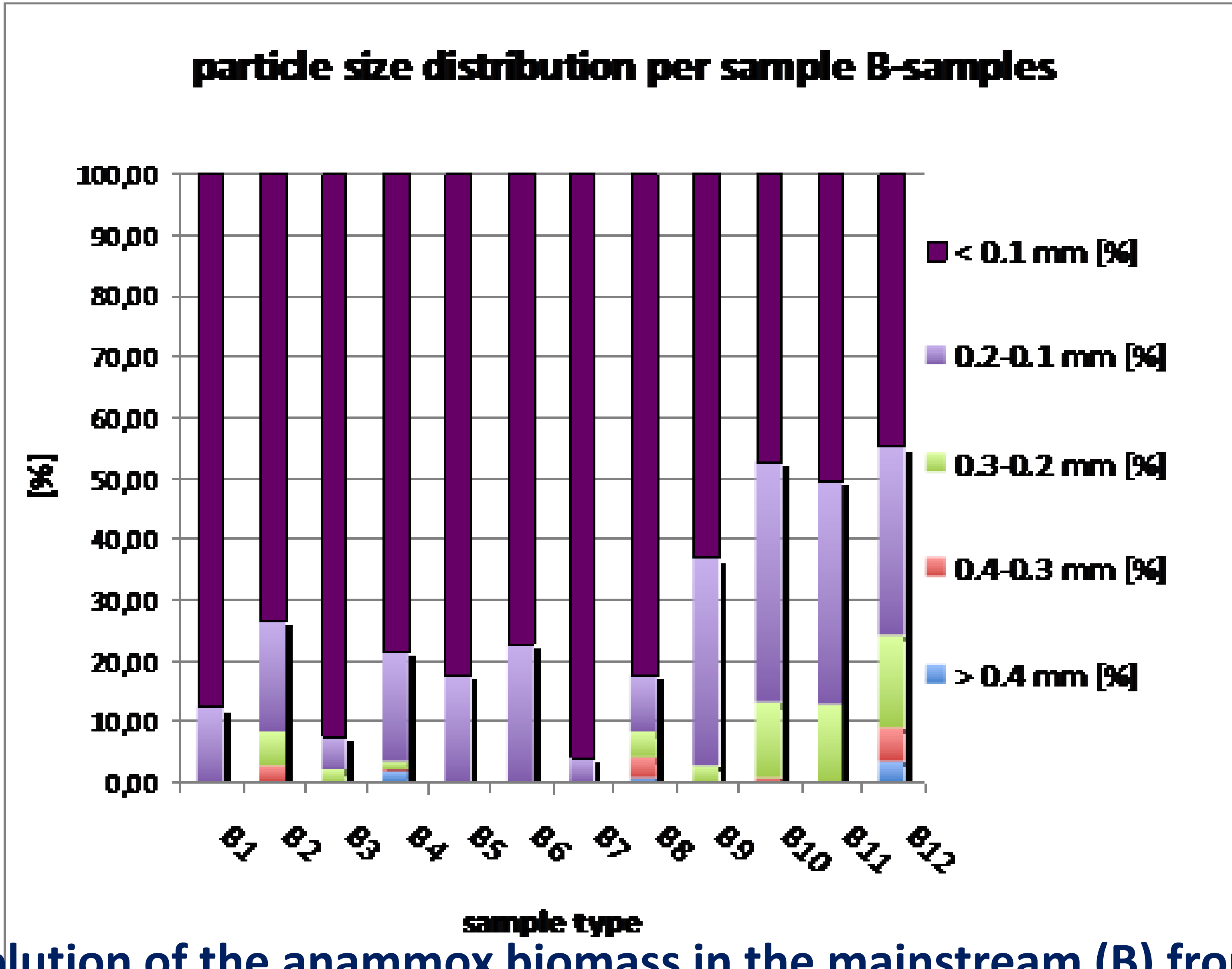


Only 25% of produced NOx from ammonia oxidation is converted to nitrate during aerobic activity test of the last sample

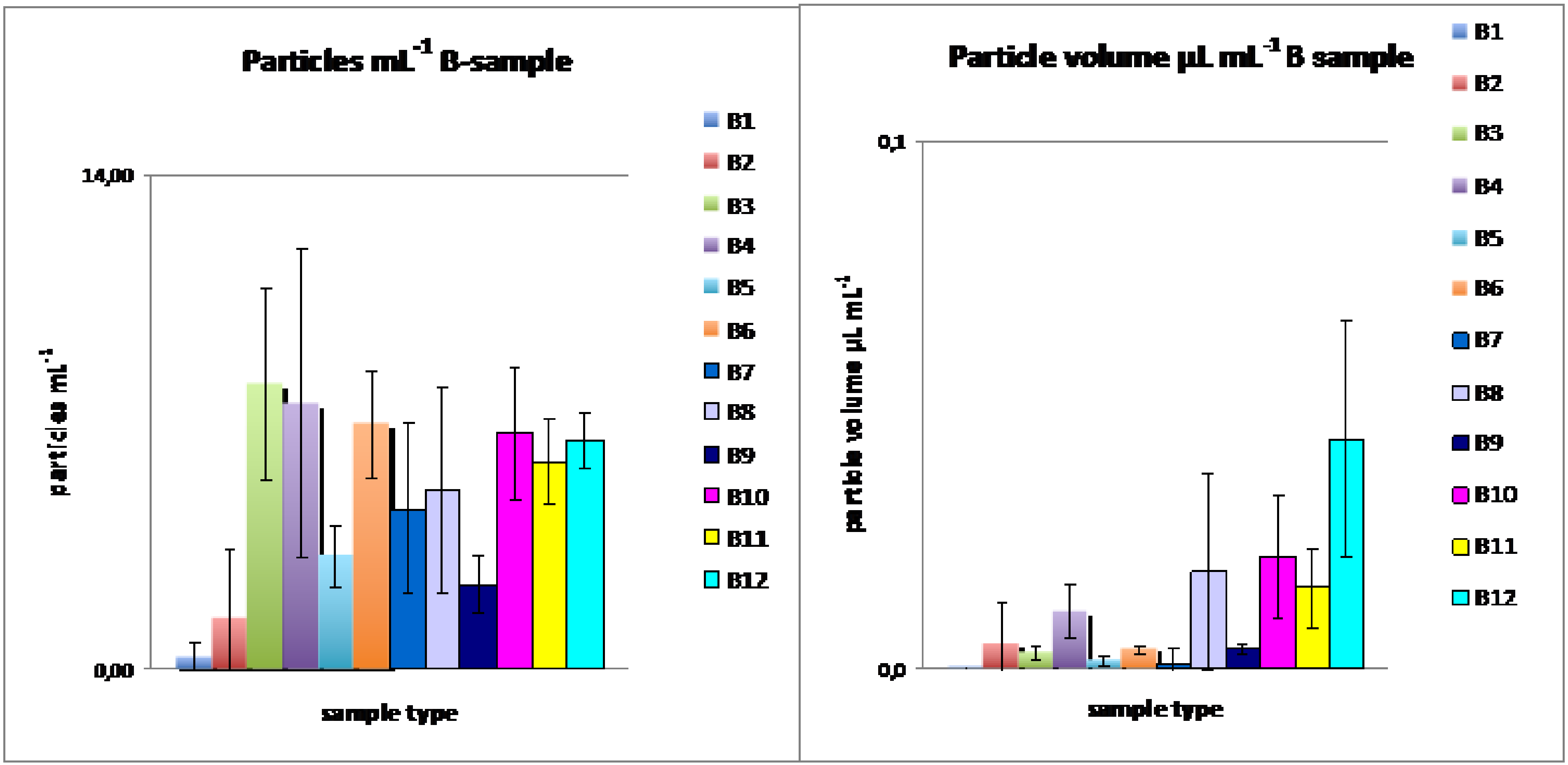




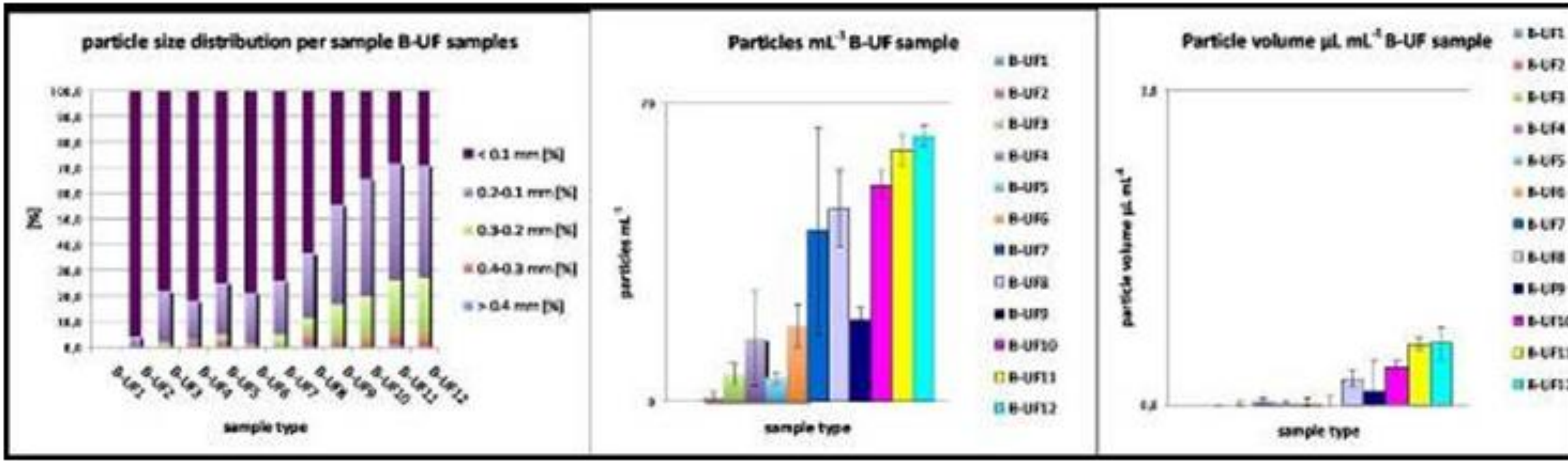
Comparison of maximum growth rates (left) and DO half saturation ko (right) of total nitrifiers (AOB+NOB) and NOB only calculated from measured DO depletion profiles of mainstream mixed liquor samples at 20°C and 30°C



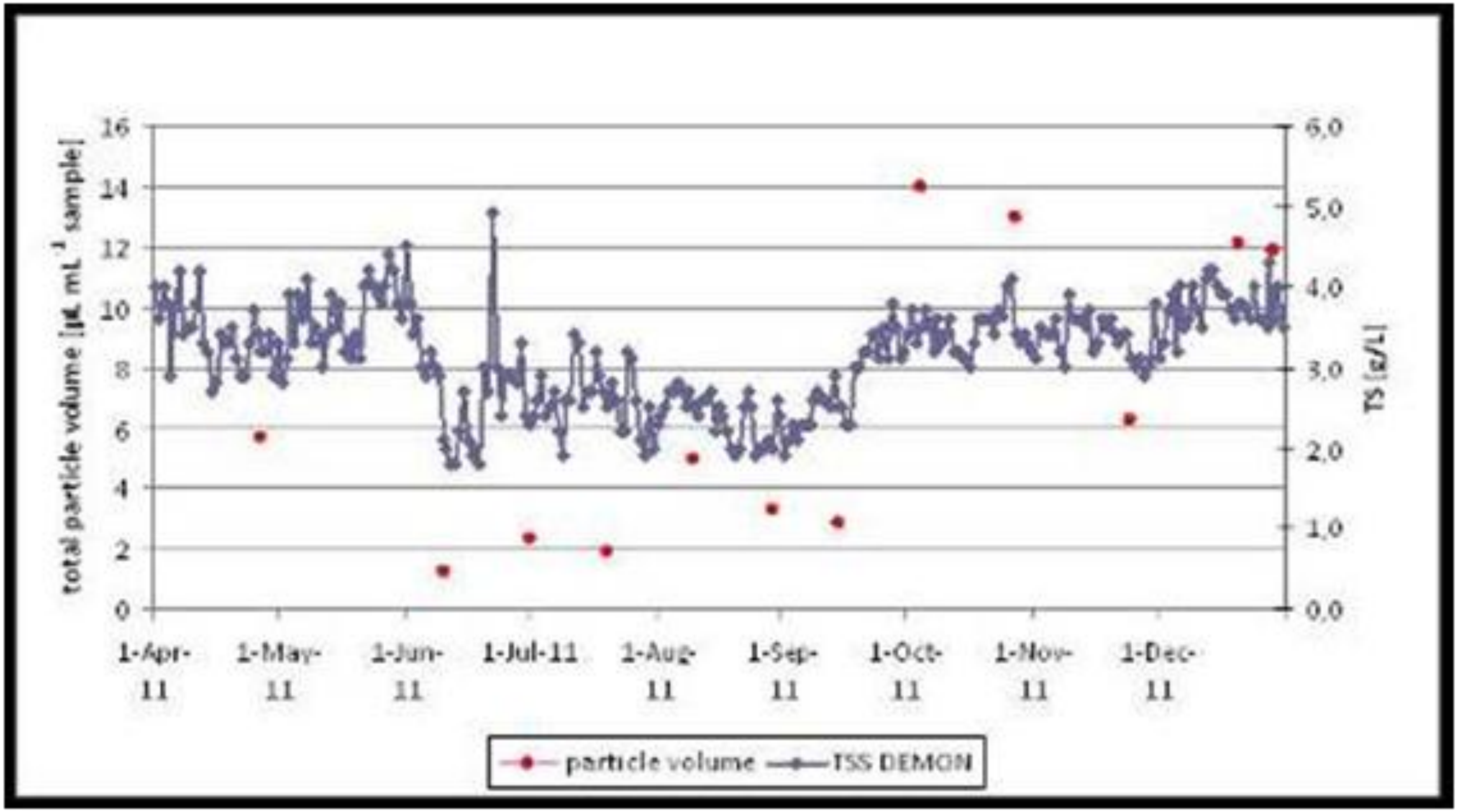
Evolution of the anammox biomass in the mainstream (B) from sampling one to twelve - distribution of granule size fraction.



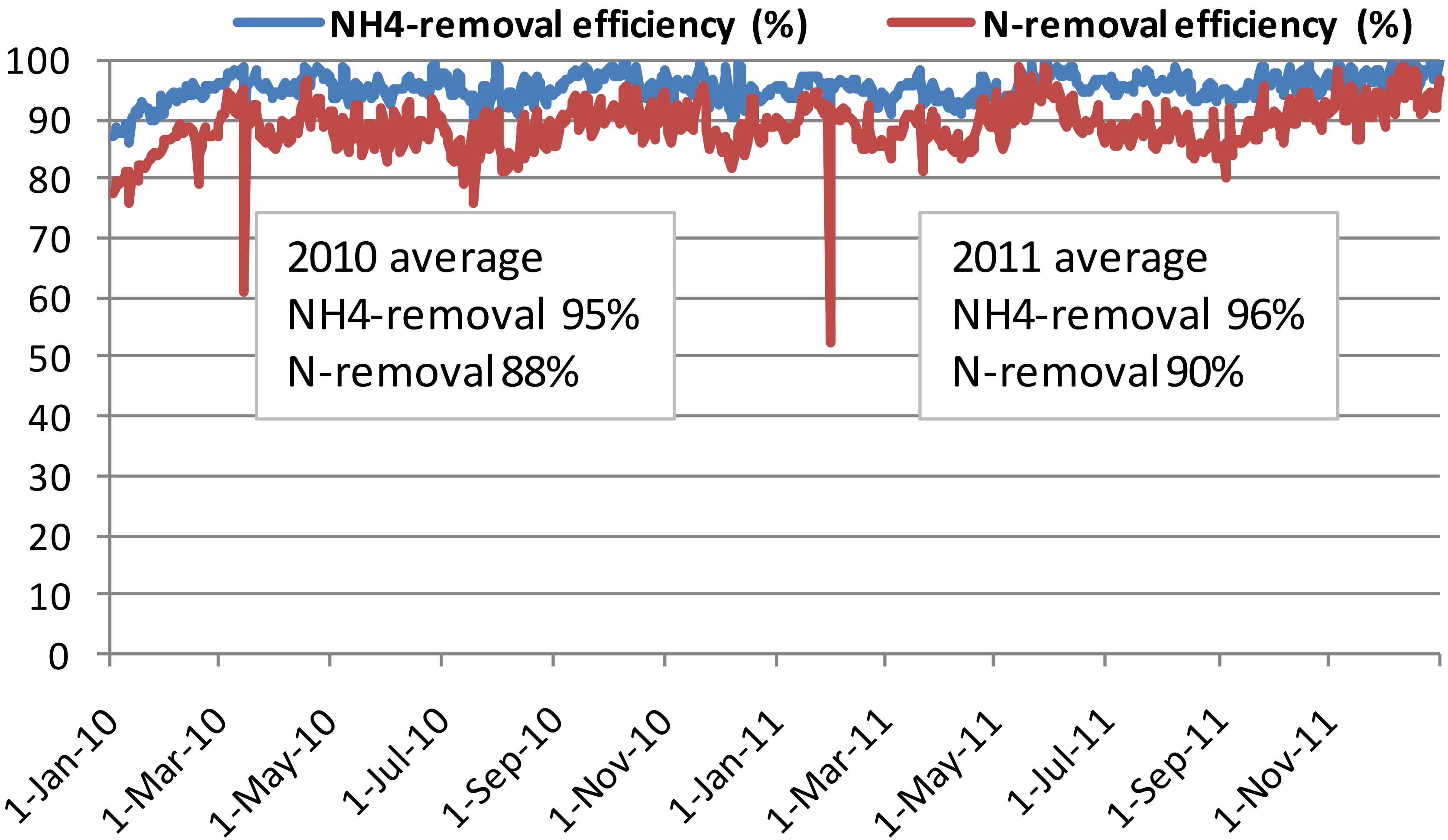
Abundance of granules mL^{-1} and estimated granule volume mL^{-1}



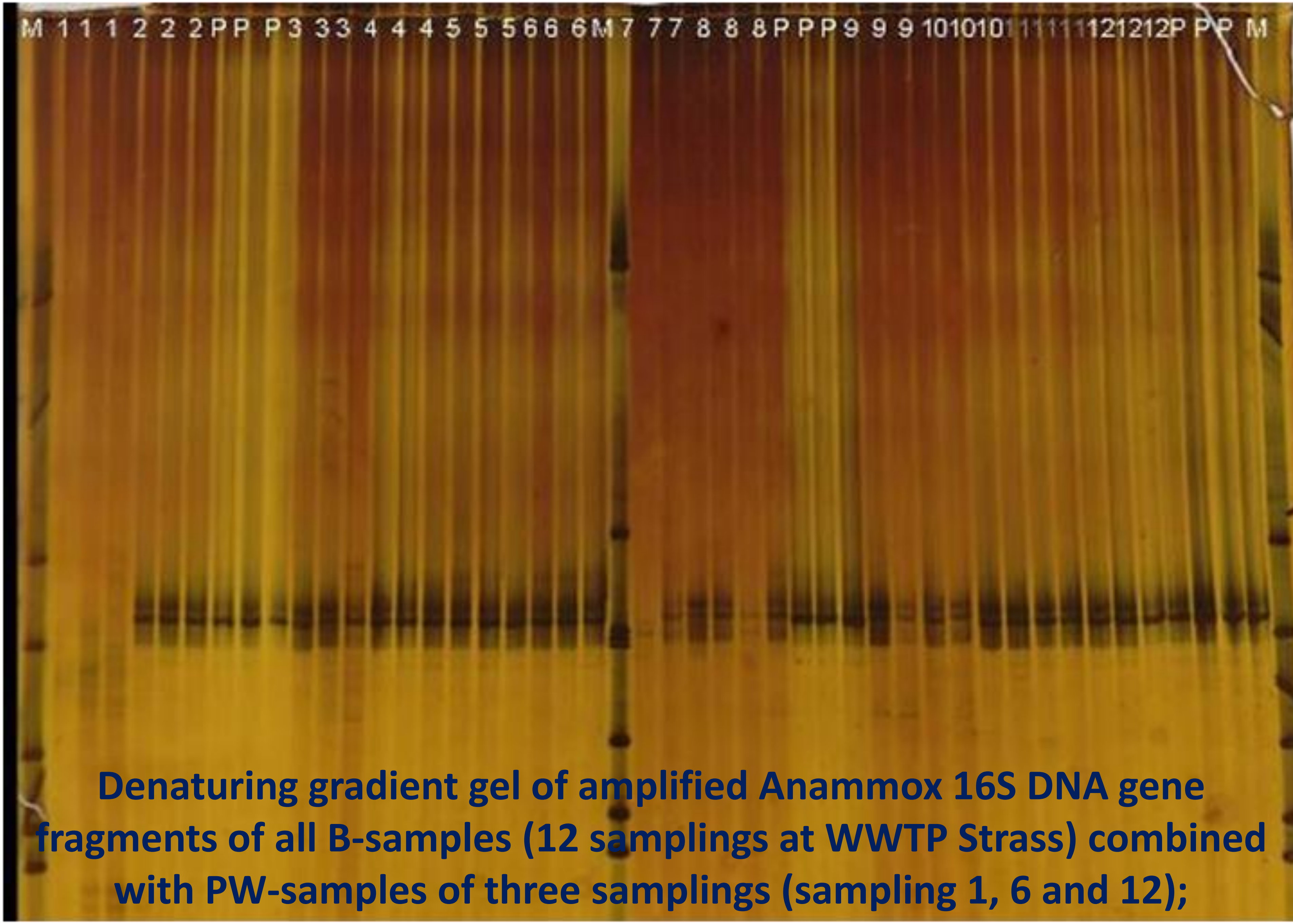
Evolution of the anammox biomass of the mainstream cyclone underflow fraction (B-UF) from sampling one to twelve; distribution of granule size fraction (left); abundance of granules mL-1 (middle) and estimated granule volume mL-1 (right)



Comparison of sidestream (PW) TSS and total granule volume in PW-samples over the sampling period



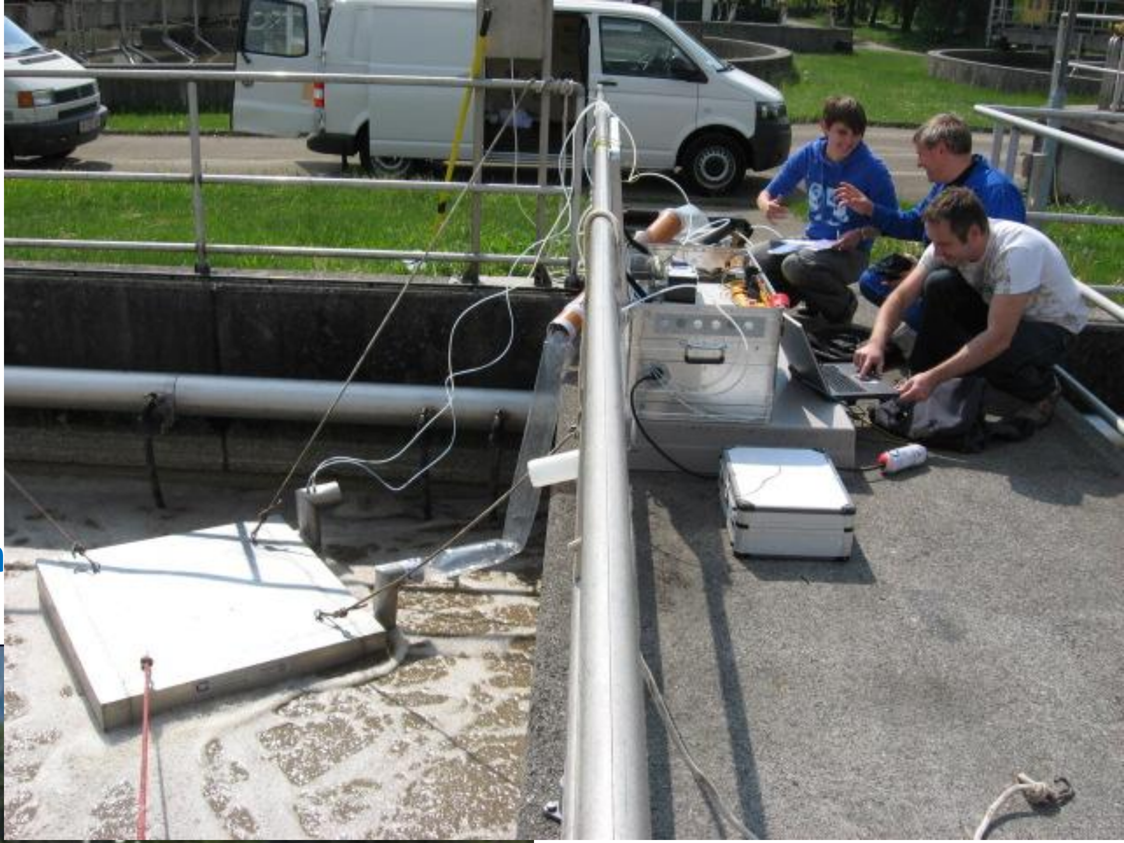
Impact of intensive bioaugmentation out of the DEMON-reactor on its treatment performance



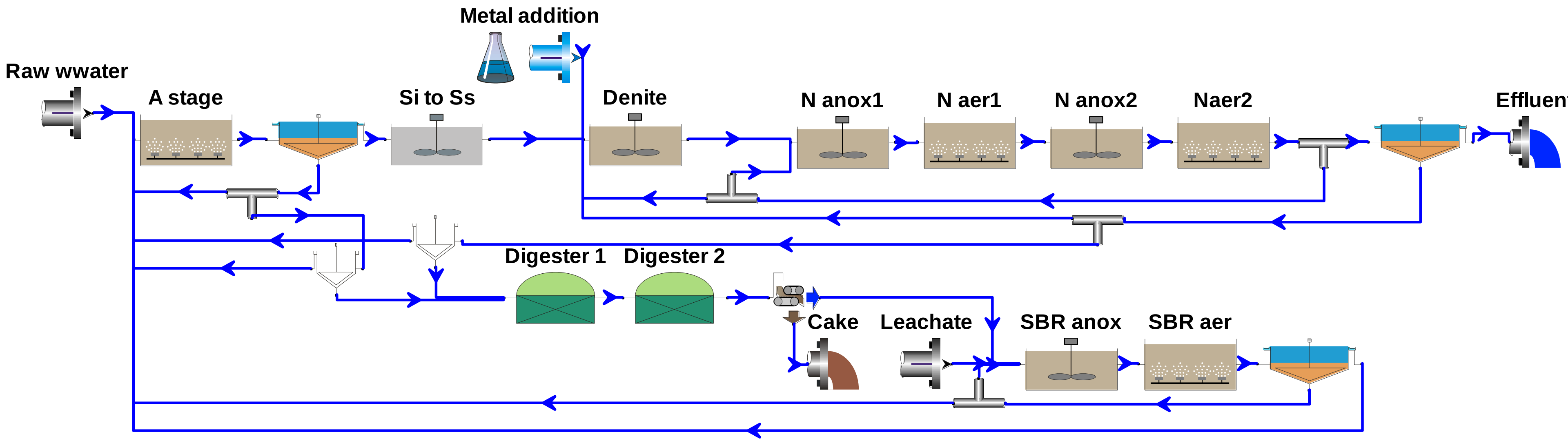
Denaturing gradient gel of amplified Anammox 16S DNA gene fragments of all B-samples (12 samplings at WWTP Strass) combined with PW-samples of three samplings (sampling 1, 6 and 12); M…Marker, P…PW-samples, numbers indicate the sampling time.

GHG-emissions (NO and N_2O as intermediate products in N-removal)

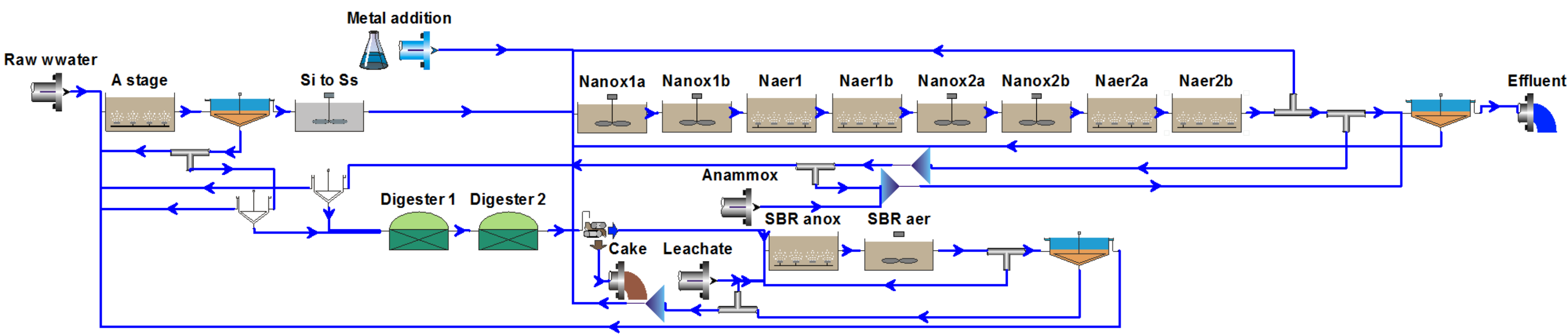
one week campaign for measuring GHG emissions (N2O, NO, NO2, CH4, CO2) in order to compare carbon footprint before and after modifications in operation and to understand process implications on the gas phase



Model configuration of the original MLE-scheme (pre-denitrification tank represents 50% of volume; object of internal recirculation stream)



Model configuration of the new SND-scheme (aerated and anoxic zones are represented by 2 CSTR each; low DO operation)



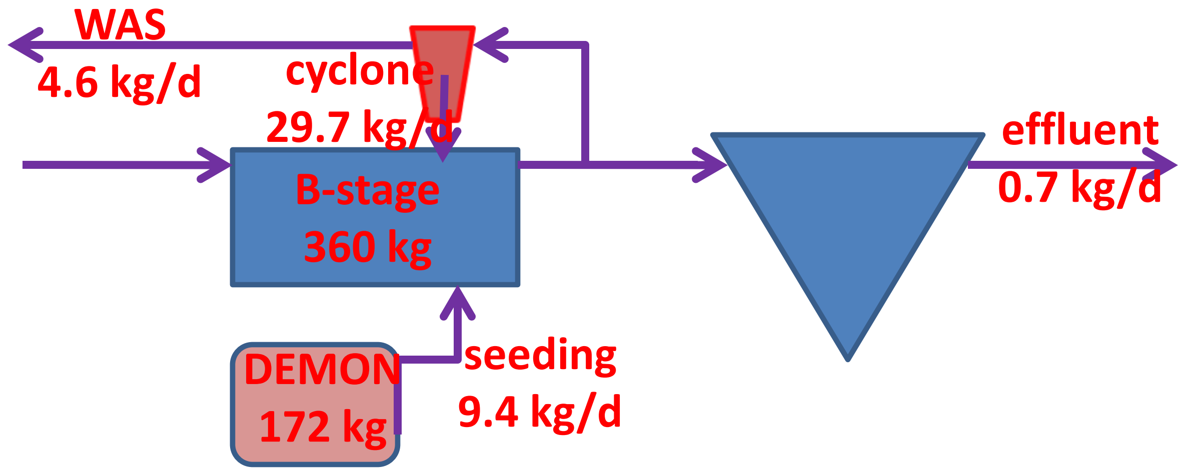
Successful process operation and NOB repression depends on 2 parameters:

- Competition between **AOB and NOB for oxygen** expressed by ko (here the same ko of 0.25 mgDO/L assumed)
- Competition between **Anammox and NOB for nitrite** expressed by ks (default for Anammox ks=1.0 NO2-N/L; for NOB ks=0.1)

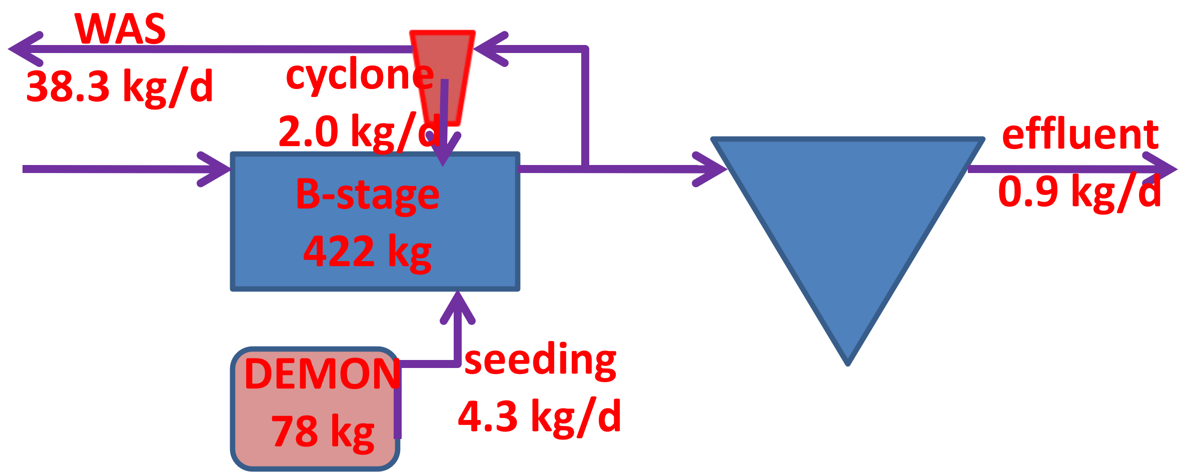
	biomass (mgCOD/L)			nitrogen (mgN/L)		
process conditions & parameters	**AOB**	**NOB**	**Anammox**	**NH4-N**	**NO3-N**	**NO2-N**
DOmax=0.35; ko=0.25; ks(NOB)=0.1; µmax(Anammox=0.1)	40	21	35	2.6	3.9	0.61
DOmax=0.40; ko=0.25; ks(NOB)=0.1; µmax(Anammox=0.1)	42	26	34	1.9	7.4	0.39
DOmax=0.35; ko=0.25; ks(NOB)=0.1; **µmax(Anammox=0.0)**	42	27	30	2.9	6.9	0.72
DOmax=0.35; ko=0.25; **ks(NOB)=0.5;** µmax(Anammox=0.1)	39	17	36	2.5	2.1	0.58

Anammox mass-balance

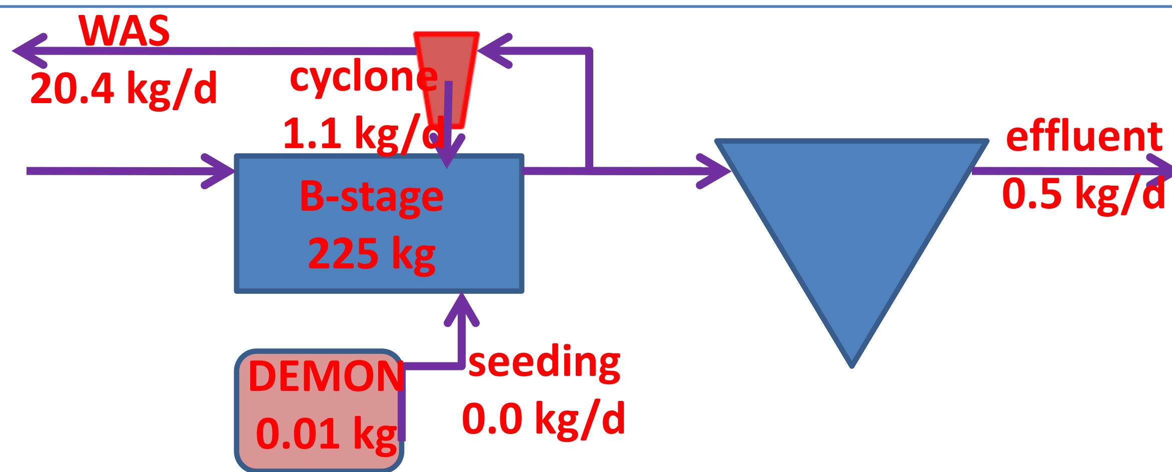
unit (kg biomass COD)



AOB mass-balance



NOB mass-balance



Overlap in Findings Bench-scale vs. Full-scale

Operation mode and aeration regime

- Bench-scale reactor A (intermittent aeration) was more successful in NOB-repression and anammox enrichment compared to the continuously aerated control.

- During the full-scale testing, the intermittent aeration pattern (either along the flow-path or the time axis) creating transient anoxic conditions was found more effective for repressing NOBs.

- ko of NOB can adapt to low DO-conditions, therefore low-DO operation is not successful.

Process engineering fairy-tales