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Aerobic conditions prevail over scarce aeration and starvation conditions for activated sludge degradation

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Minimizing excess sludge production in small scale, decentralized WWtreatment systems

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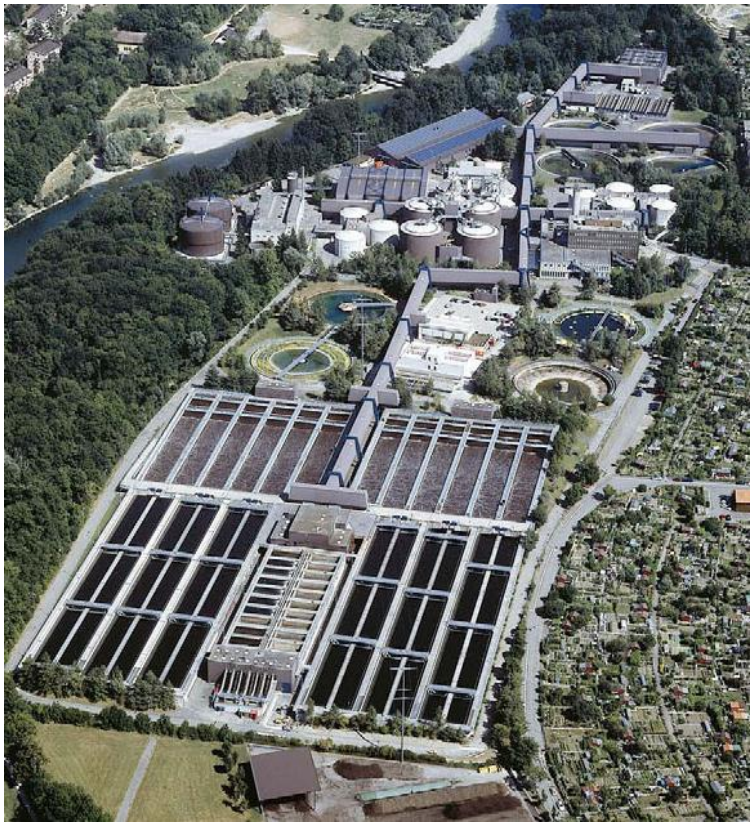
Wastewater treatment in the future is diverse

Centralized, large scale



www.stadt-zuerich.ch

Benefits:

- Efficient (finances, energy)
- Reliable by close monitoring

Decentralized, small scale

www.busse-is.de

Benefits:

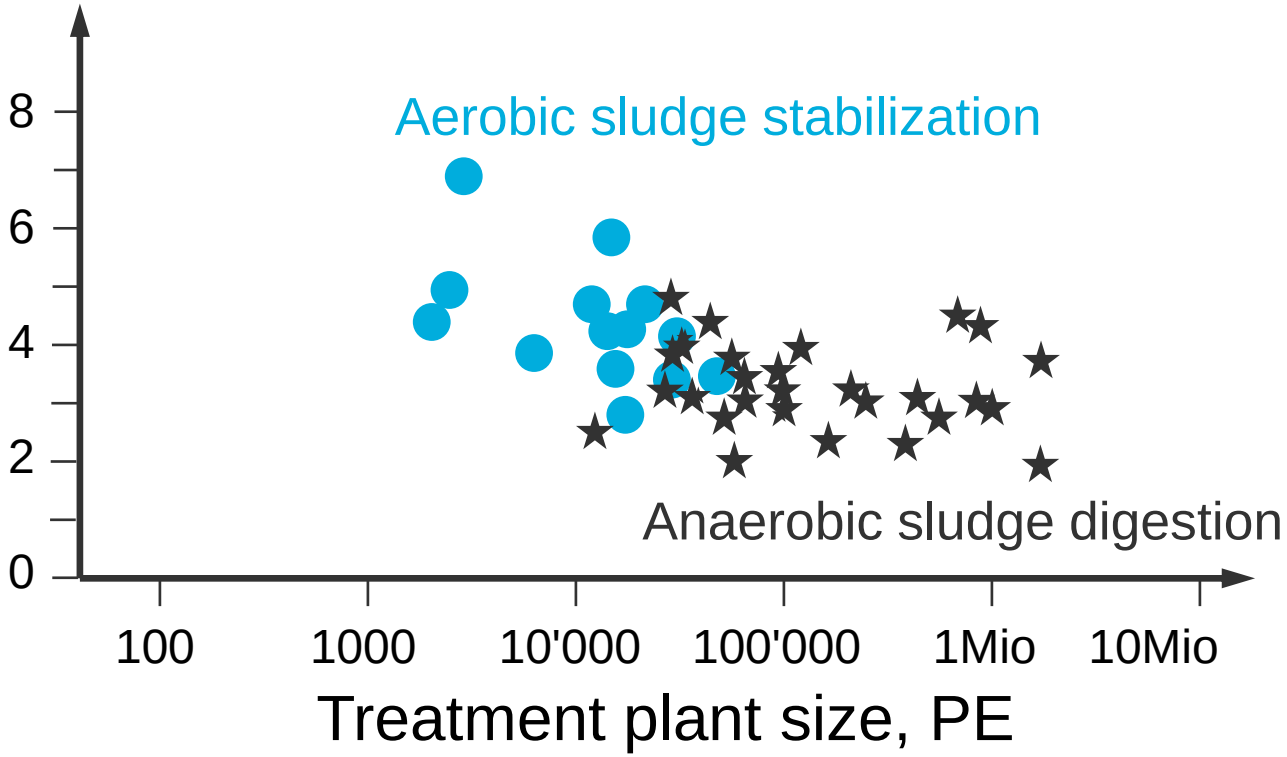
- Limited sewer needs

  Total cost for (2004, CH):
  WWTP: 100 Euro p^{-1} yr^{-1}
  Sewer: 230 Euro p^{-1} yr^{-1}

- Possibility for local fresh-water production, heat recovery

… and so are sludge treatment technologies

Energy demand for wastewater treatment
W/Person (1 W = 9 kWh/person.year)



Treatment data from: Kolisch et al. (2010) KA 57(10), 1028-1032

Sludge handling in small scale, decentralized WWTP

www.klaro.eu

WWTP Characteristics

- Limited accessibility
- Low monitoring and maintenance

Sludge handling requirements

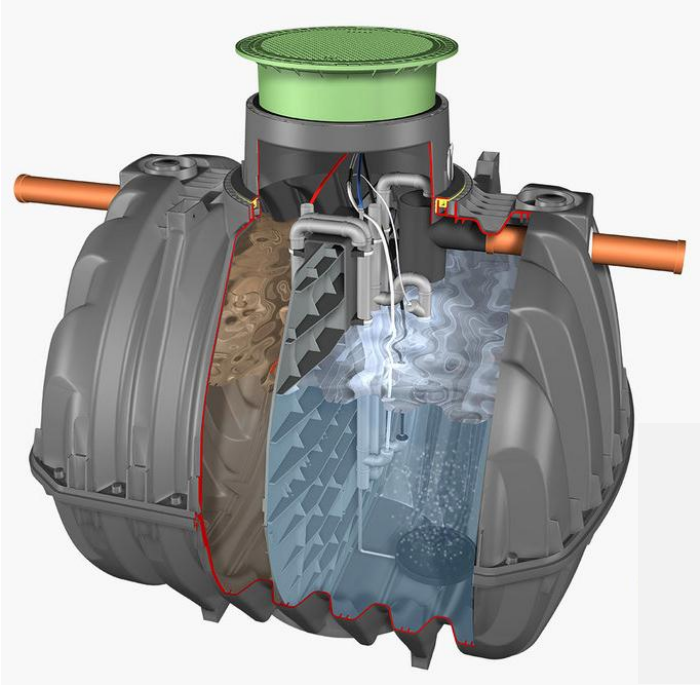
- Simple and reliable technology
- Priority on Hygenization
- Reliable operation
- Low maintenance and service
- Odor free

Current practice and optimization

Current practice

<u>Aerobic sludge stabilization</u>
+ Low odor
+ Low gas
- Energy requirement
- Storage volume

<u>Sludge transporting</u>
+ P-recovery
+ Energy recovery
- Transportation
  - GHG-emission
  - Costs
  - Handling



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Optimization potential

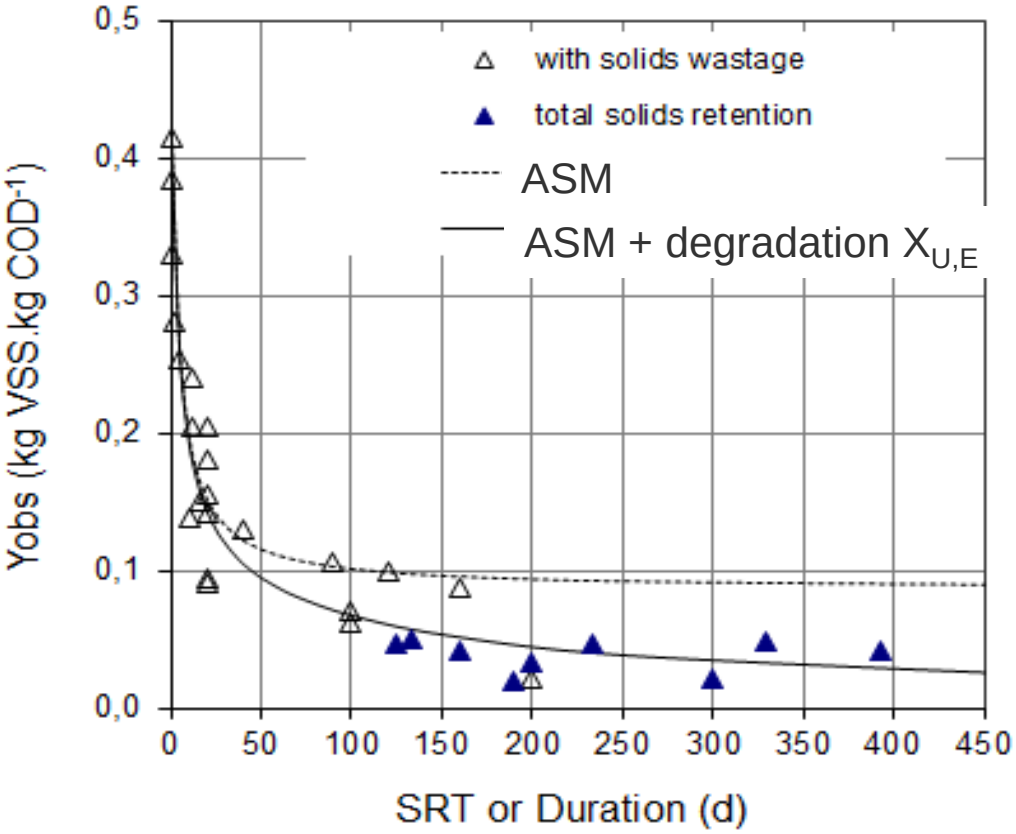
<u>Enhanced sludge degradation</u>
→ Smaller storage volume
→ Fewer transports

<u>Not fully aerobic sludge degradation</u>
→ Economy of energy

Conditions for enhanced sludge degradation

Effect of Solid Retention Time (SRT) on sludge reduction

Review on membrane bioreactor studies studies



Spérandio et al. 2013, WS&T (67), pp. 789-796

<u>Finding</u>

SRT can be used for sludge reduction

<u>Questions</u>

- Origin of variation in datapoints?
- Other control parameters than SRT?

Conditions for enhanced sludge degradation

Effect of Redox potential and Starvation on sludge reduction

Key Parameter for sludge reduction	Effective-ness	Mechanism	Questions	Publications
Low redox potential (no or low level aeration, non methanogenic)	variable	• Iron reduction • Different compounds degradation	• SRT vs. Redox effect? • Additional conditions? • Mechanism: in depth	• *Saby et al. 2003, Wat. Res. (37)* • *Novak et al. 2007, Wat. Env. Res. (79)* • *Park et al. 2006, Wat. Env. Res. (78)* • *Chon et al. 2011, Wat. Res. (45),* • *Ramdani et al. 2012, Wat. Res. (46)*
Starvation	uncertain	• Cryptic growth • Viral attack • Predation	• Starvation effect? • Mechanism?	*Chon et al. 2011, Wat. Res. (45), pp. 6021-29*

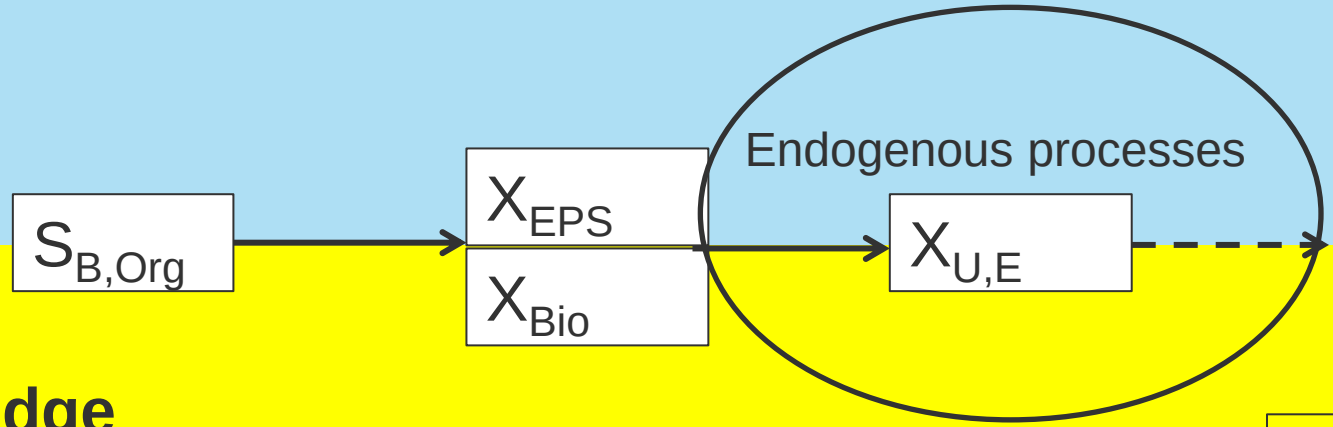
Research approach

Starvation

Redox potential

SRT

conditions



Net sludge production

Biochemical composition of sludge fractions

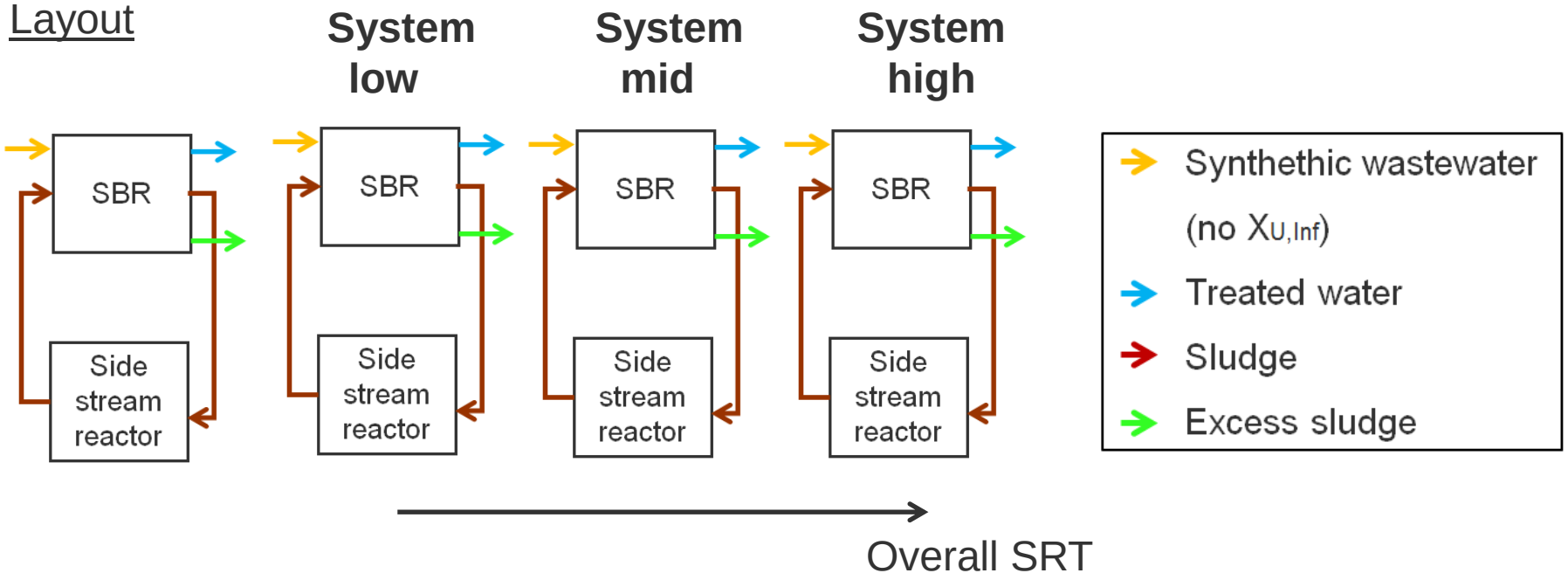
Effects and mechanisms

Degradation rates of sludge fractions

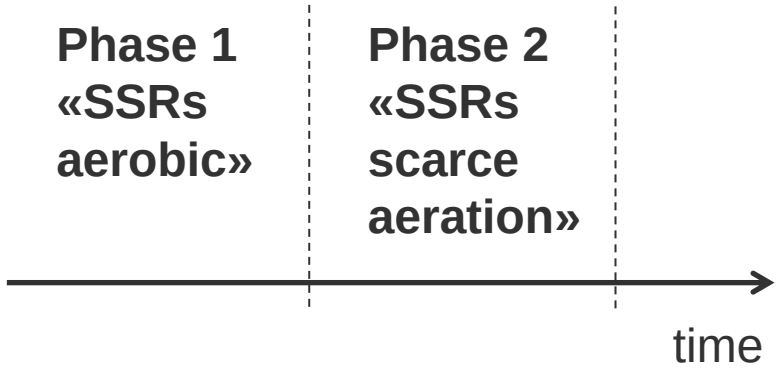
Role of extracellular enzymes

Investigating the effect of SRT, Aeration and Starvation

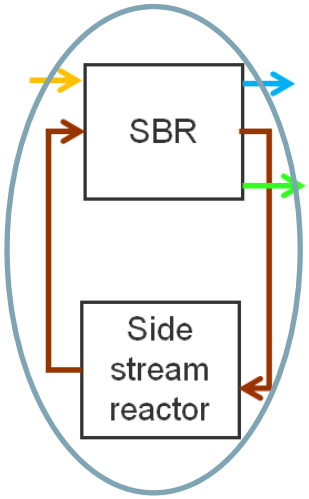
Layout

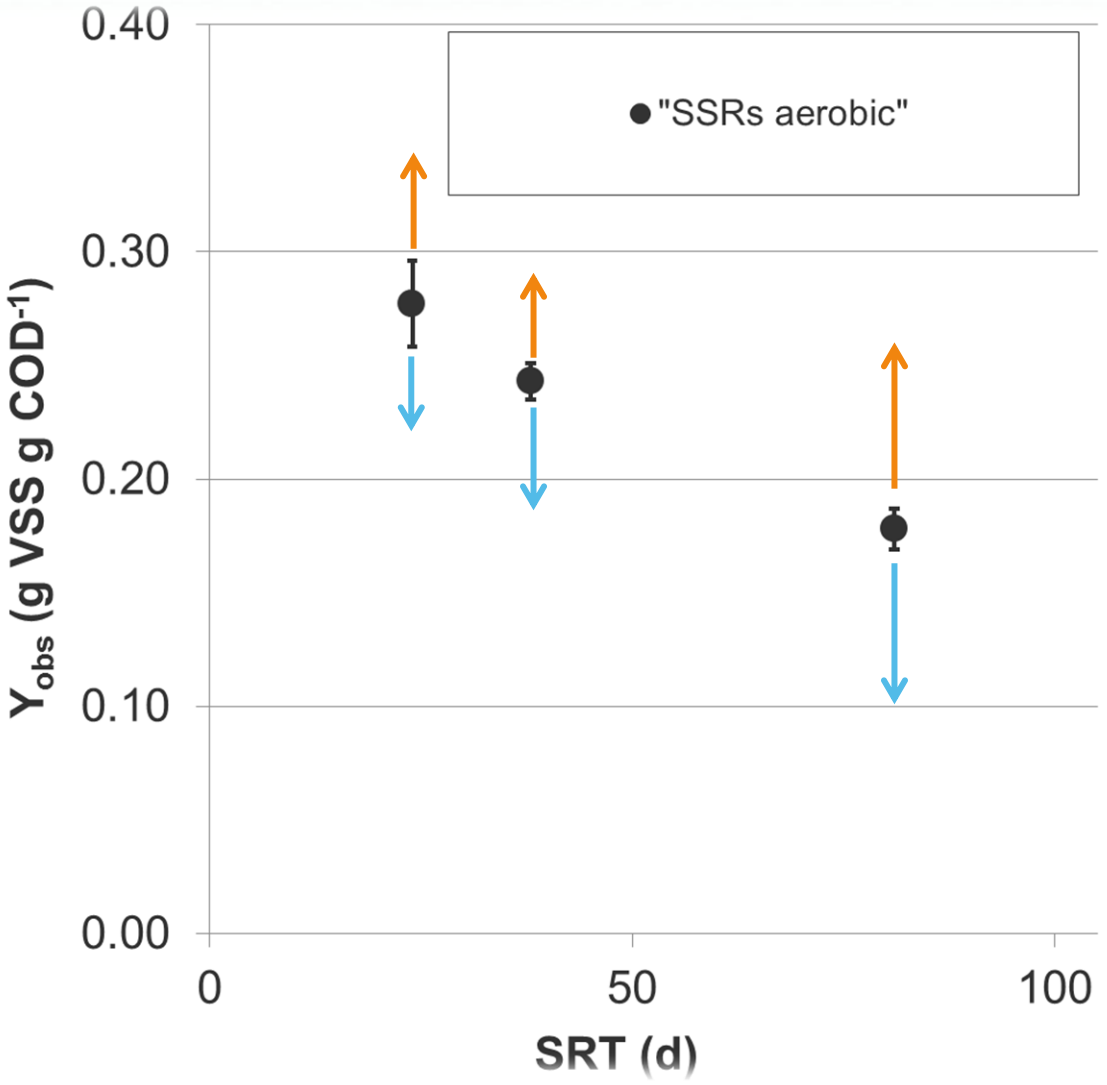


Phases



Effect of SRT and Aeration – Phase 1 «SSRs aerobic»



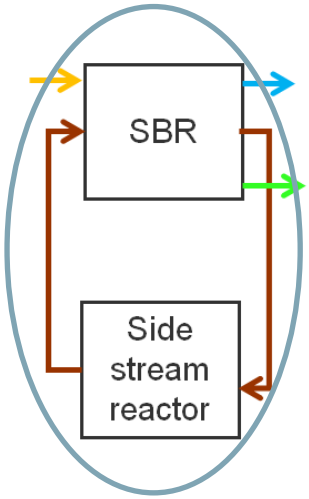


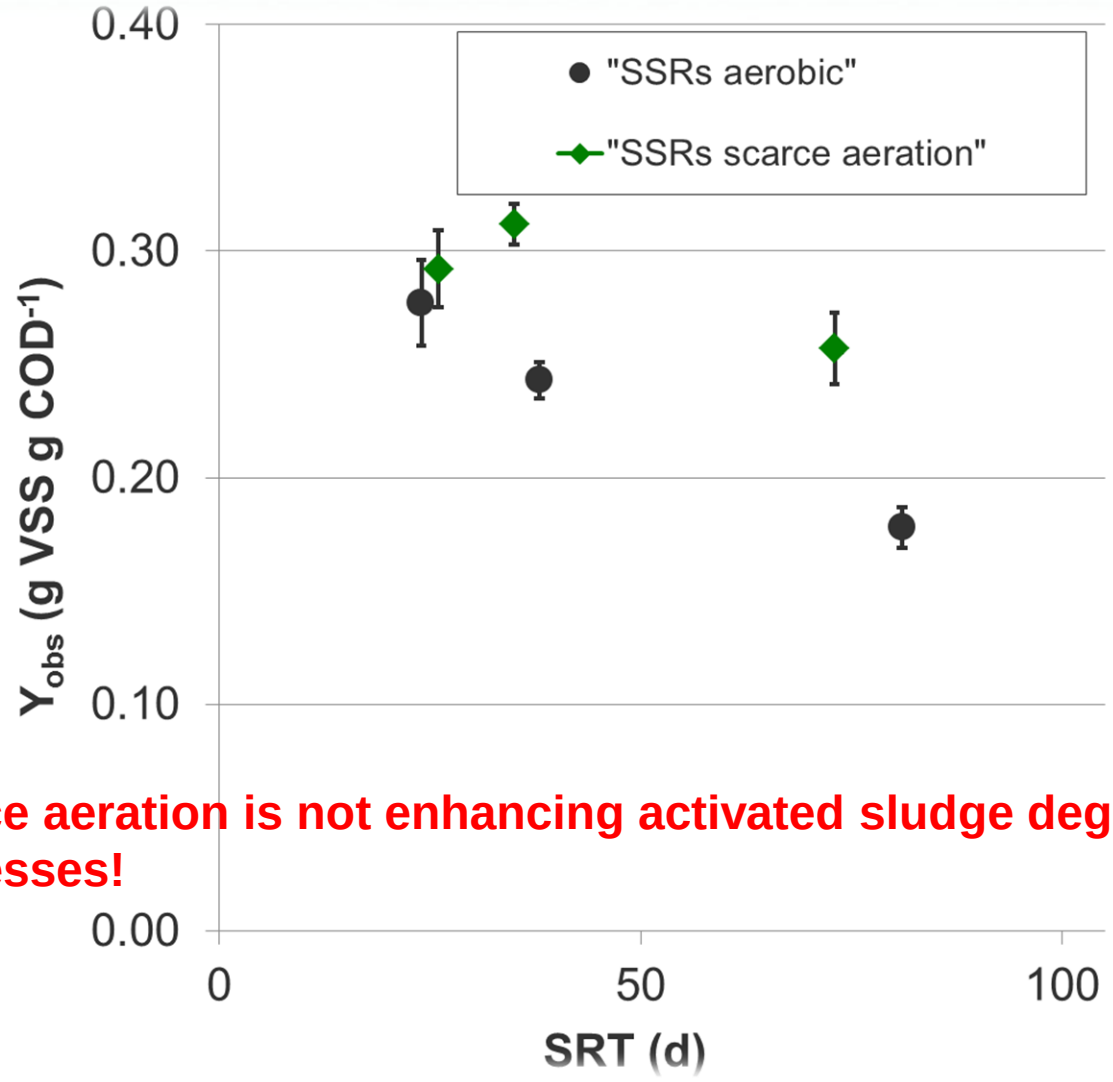
ASM

Expectation scarce aeration

ORP-research

Effect of SRT and Aeration – Phase 1 «SSRs aerobic»

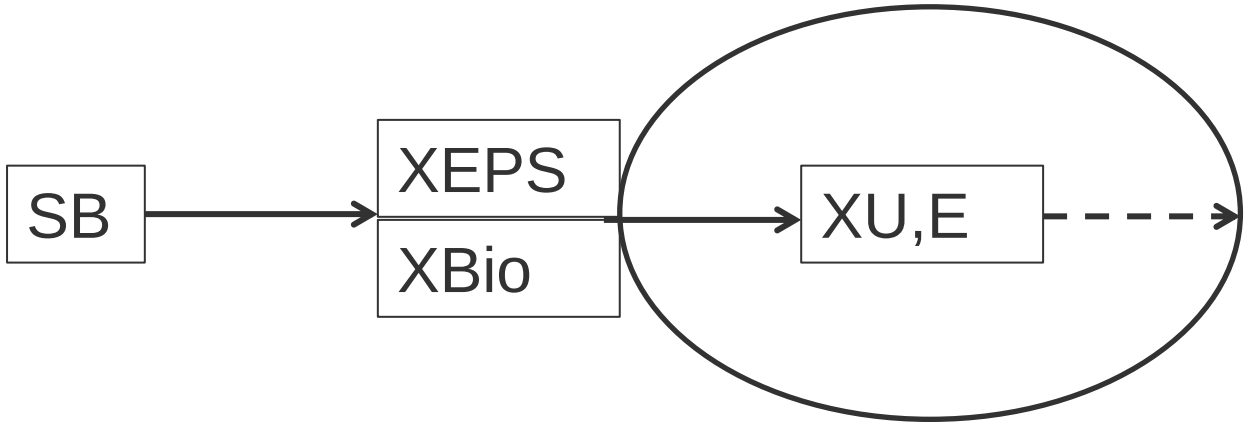


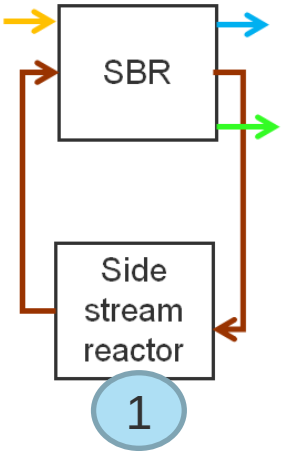


Scarce aeration is not enhancing activated sludge degradation processes!

Effect of starvation - Methodology

Enhanced sludge degradation by starvation?





Endogenous processes

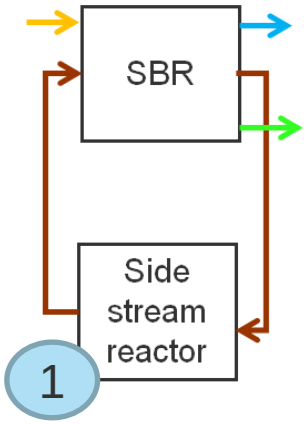
- Lysis
- Cryptic growth
- Predation
- Viral attack
- Cell maintenance
- …

Phase 1 «SSRs aerobic»

Measurement:
Volatile suspended solids (VSS)

Effect of starvation – Simulation required

Laboratory systems



Phase 1 «SSRs aerobic»

Simulations

Reactor model

Simulation platform: Aquasim

Inupt parameters

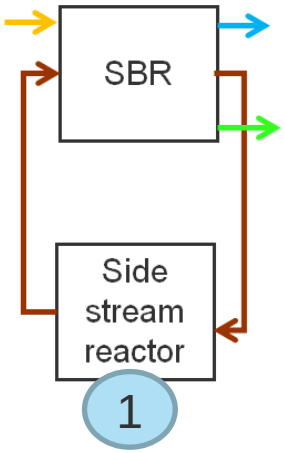
Biokinetic model: ASM3, Parameters: *Gujer et al. (2000), WS&T (39), pp. 183-193.*

Comparison

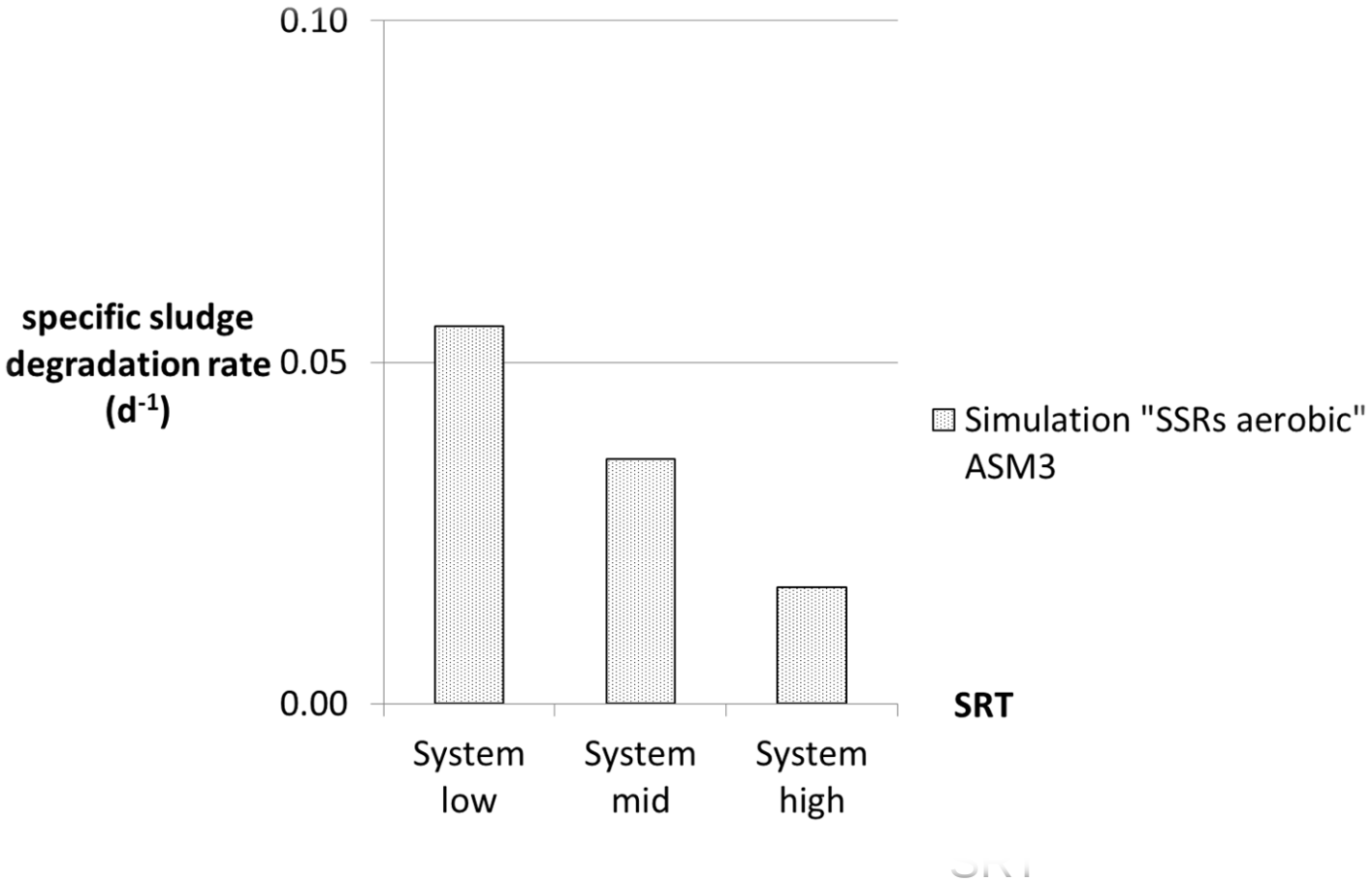
1. Sludge degradation in SSR
Simulation scenarios

- Default Processes and Parameters
- Degradation $X_{U,E}$

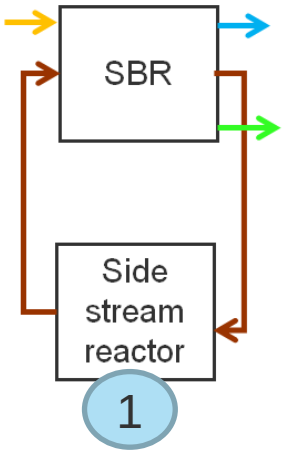
Effect of starvation – Results SSRs



Phase 1 «SSRs aerobic»



Effect of starvation – Results SSRs



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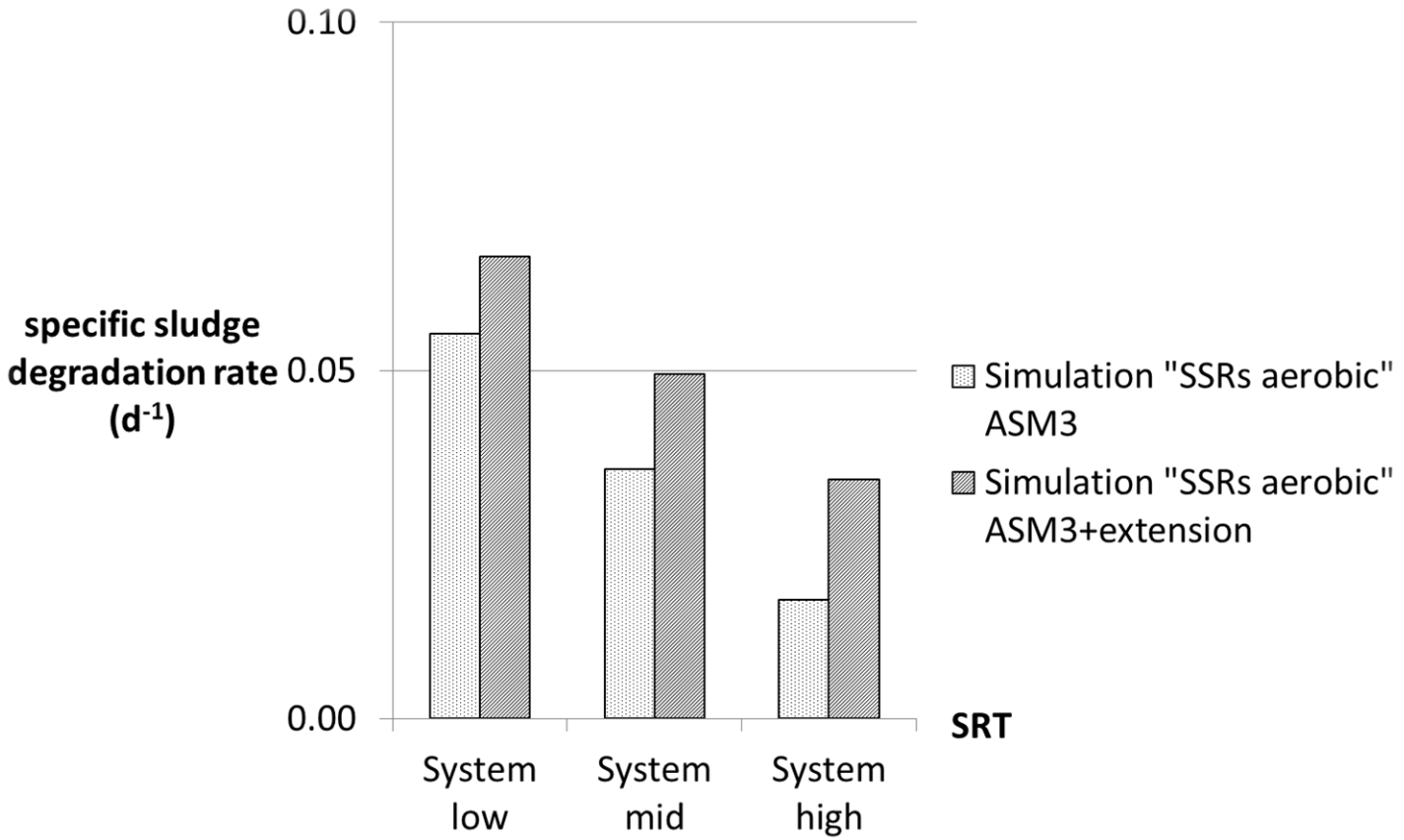

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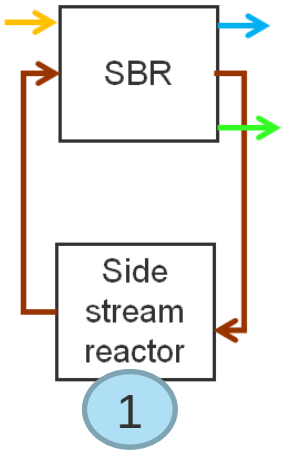

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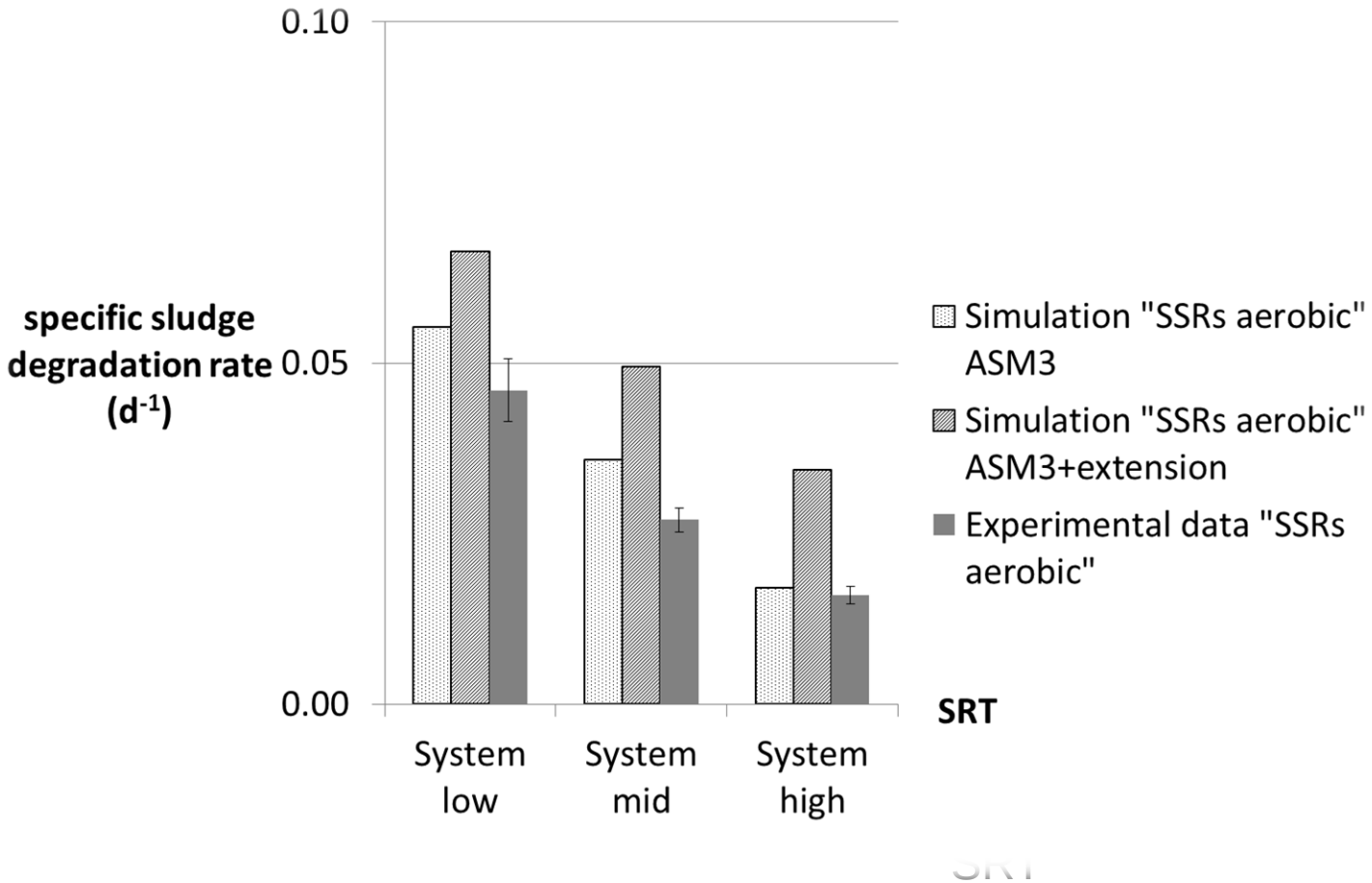
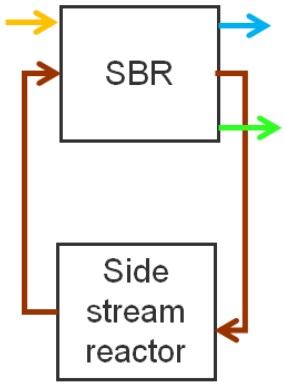


Specific sludge degradation rate in SSRs is similar or slightly slower than ASM3 kinetics!

Effect of starvation – Simulation required

Laboratory systems



Phase 1 «SSRs aerobic»

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Inupt parameters

Simulations

Simulation platform: Aquasim

Biokinetic model: ASM3, Parameters: *Gujer et al. (2000), WS&T (39), pp. 183-193.*

Comparison

1. Sludge degradation in SSR

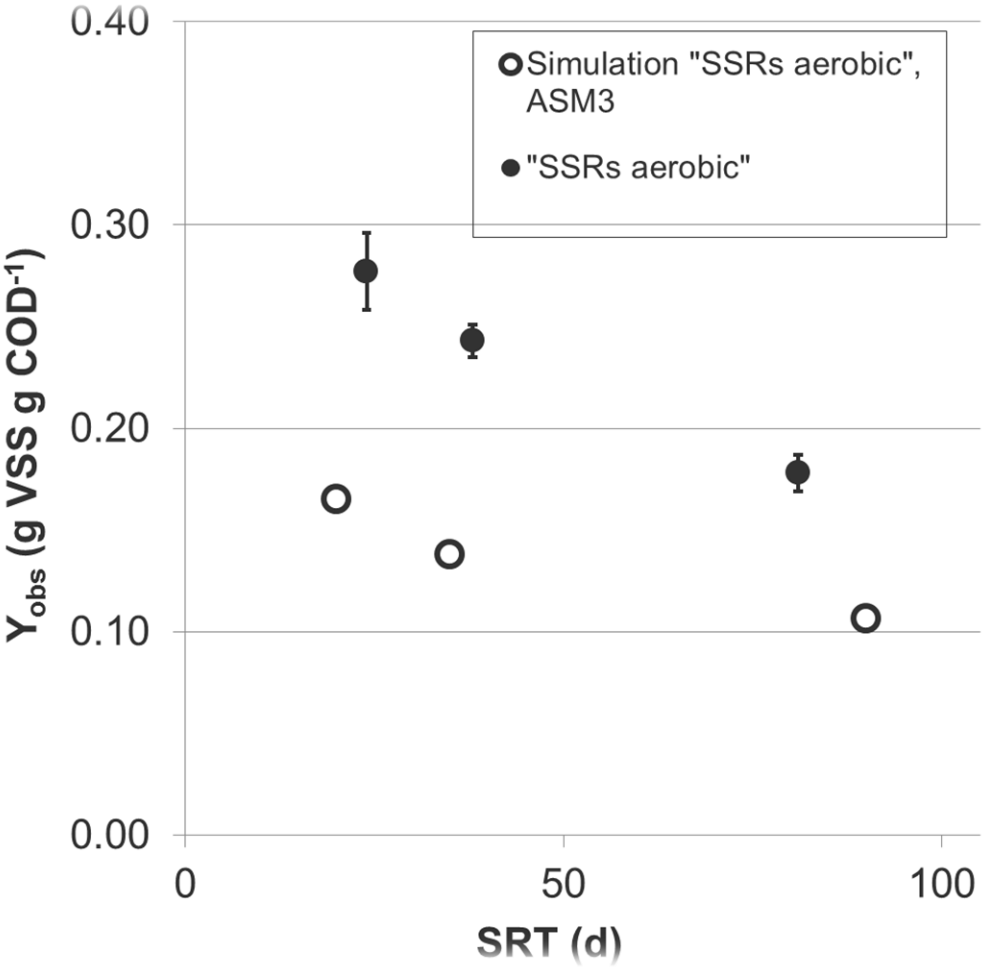
Simulation scenarios

2. Overall sludge degradation

3. Sludge degradation in the SBR

Overall System degradation behavior

Degradation kinetics based on overall sludge production



Explanations differences

X simulation errors

X substrate

(x) Measurement errors

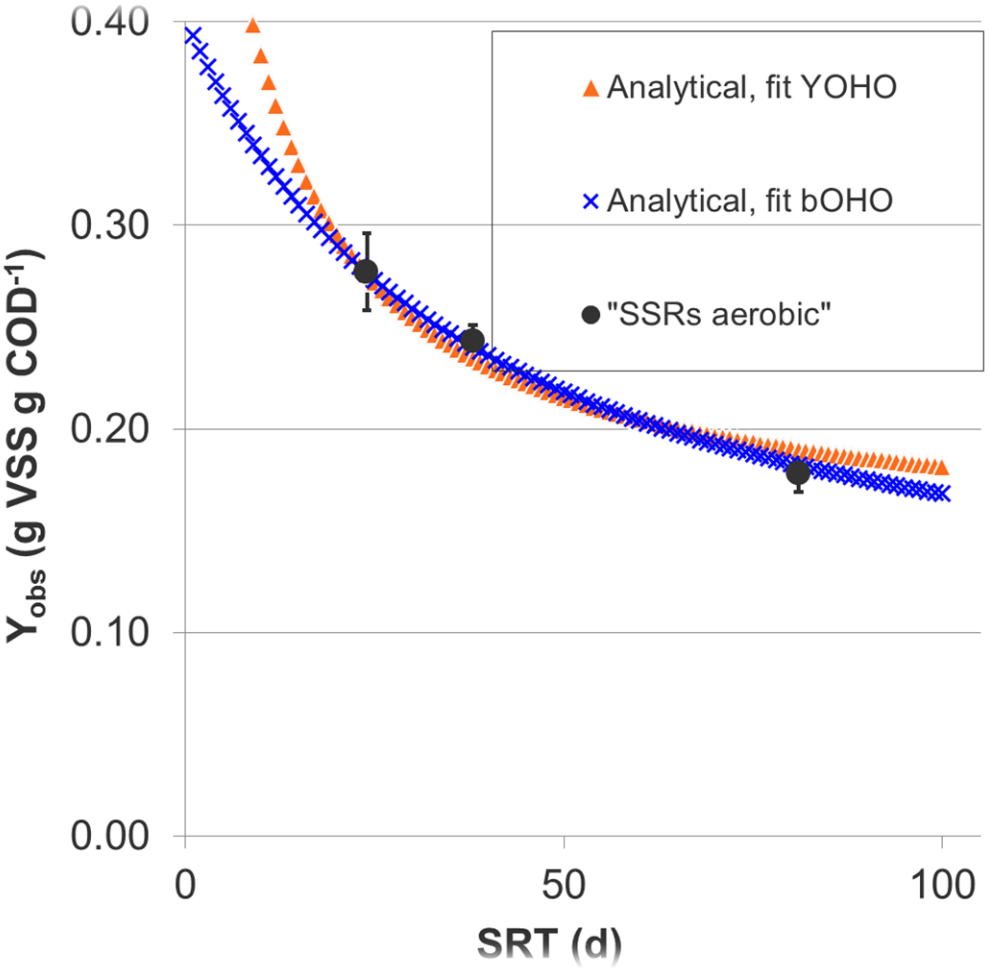
(x) pH

Feeding mode

(Novak et al. 2011, Biosolids and Residuals Lobos et al. 2008, J. of membrane science)

Overall System degradation behavior

Degradation kinetics based on overall sludge production



Scenario 1:

- b_{OHO}=0.2 d^{-1} (default)
- growth yield is different

→ Y_{OHO}=0.95 mg COD mg COD^{-1}

Scenario 2:

- Y_{OHO}=0.54 mg COD mg COD-1 (default)
- decay rate is different

→ b_{OHO}=0.04 d^{-1}

SBR and thus overall system sludge production are extraordinary high

Closing

… Minimization of excess sludge production in small scale decentralized WWtreatment systems

Summary

- Aerobic SRT has the expected sludge reducing effect
- Scarce aeration condition decreases the rate of endogenous processes
- Energy-substrate starvation is not enhancing sludge degradation processes

Outlook

- Mechanistic insights: Measurements of Active biomass, EPS, Enzymatic activities

Conclusion

- Design of sludge minimization process: Aerobic SRT is most reliable and applicable in decentralized systems, e.g. aerated sludge storage is recommended
- Use of electron acceptor limitation for sludge minimization: careful evaluation of working conditions and key mechanisms is still required
- Filling mode of the activated reactor could impact on sludge production