Three-loop Aquaponics Systems

Chances and challenges

22-03-2016, Simon Goddek

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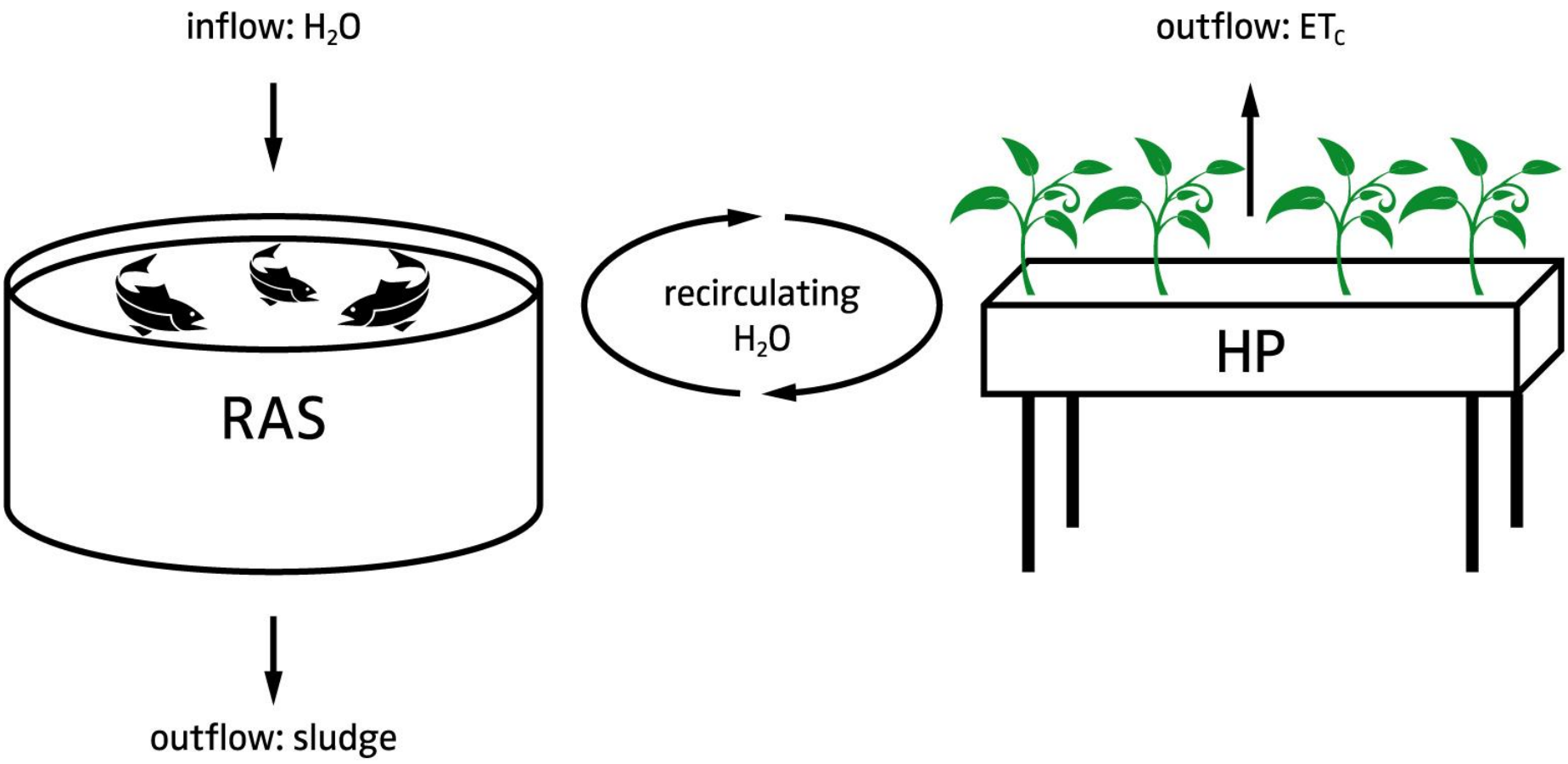
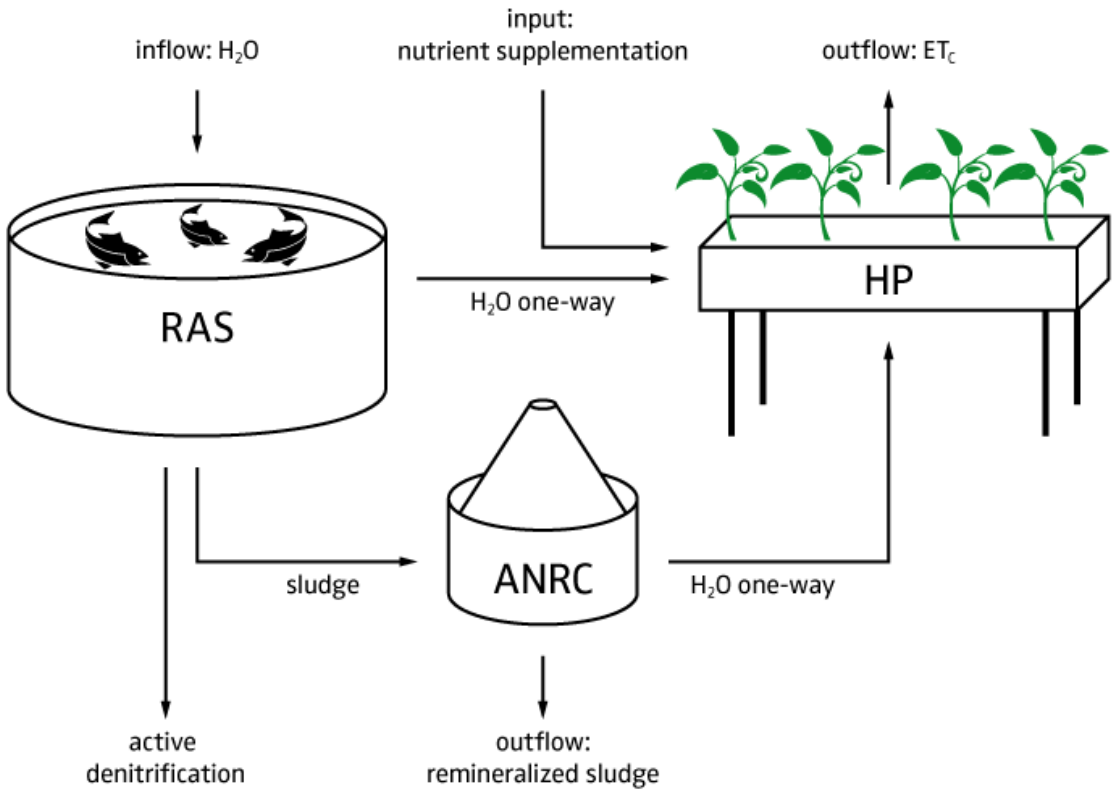
One-Loop System

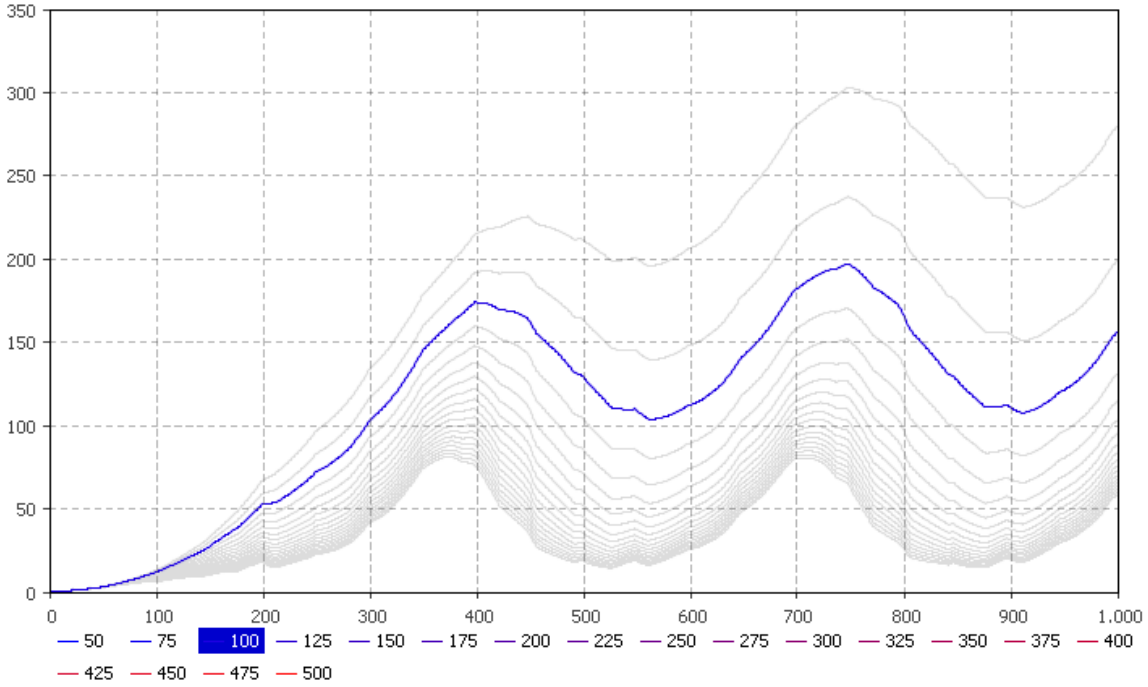


Multi-Loop System Design Criteria

- ET_c determines:
  - RAS Quality
  - HP Inflow
- Light Intensity
  - Artificial
  - Natural
- Anaerobic Nutrient Remineralization Component (ANRC)

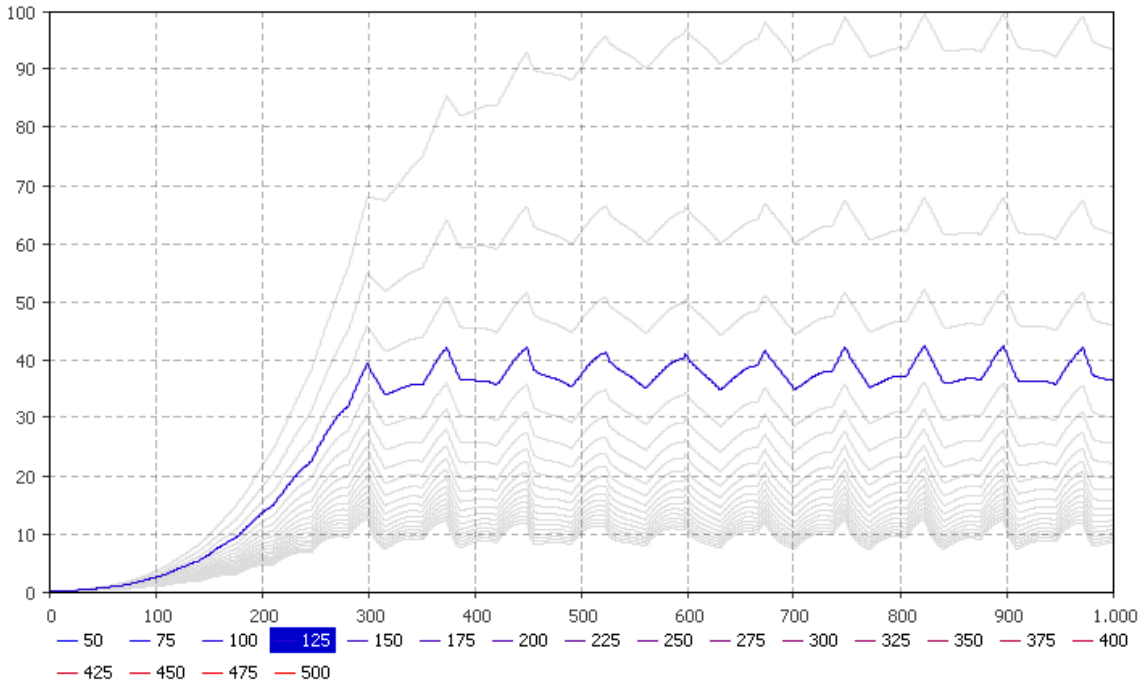


Artificial vs. Natural Light



Parameter variation experiment estimating the RAS-derived N-NO3 concentration (y-axis) based on different cultivation area options under natural light conditions. (Goddek et al., 2016; in peer review)

Artificial vs. Natural Light #2



Compared to the exclusive use of natural light, the application of artificial light for industrial production shows a different picture. The y-axis shows the RAS N-NO3 concentration, whereas the x-axis display the size of the respective cultivation areas. (Goddek et al., 2016; in peer review)

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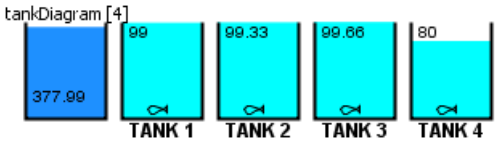
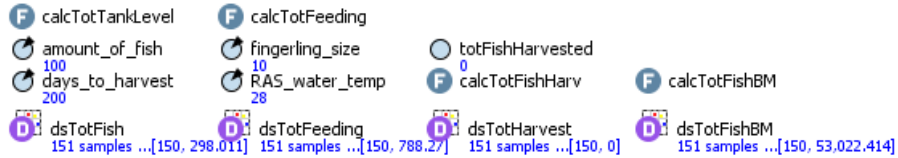
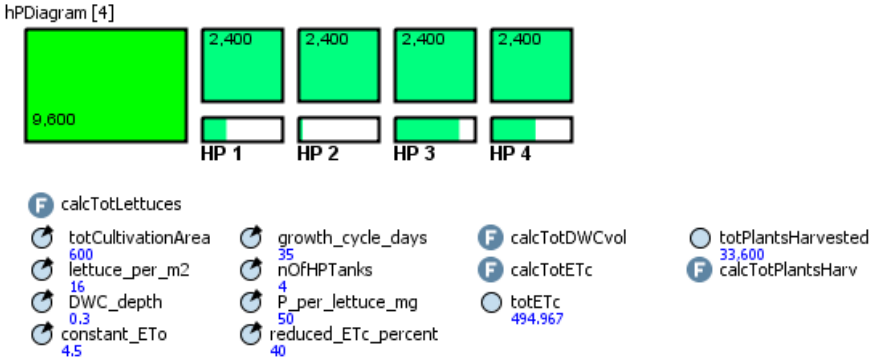
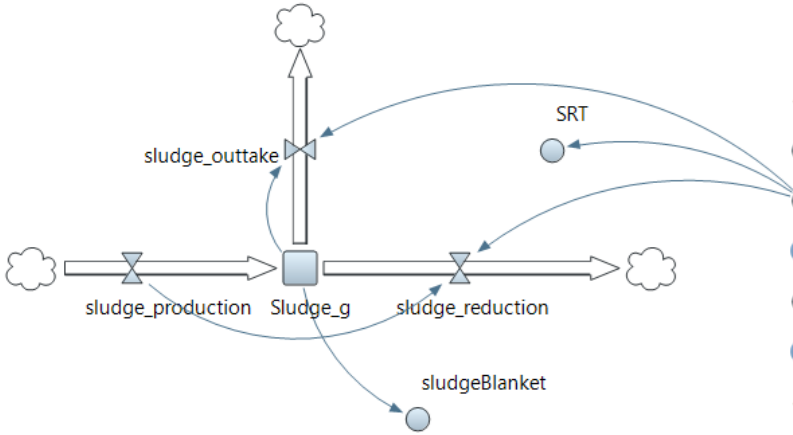
AnyLogic Model

- Agent Based modelling
- Predicting mass balances
- Parameter optimization
- Output: Design and sizing decisions



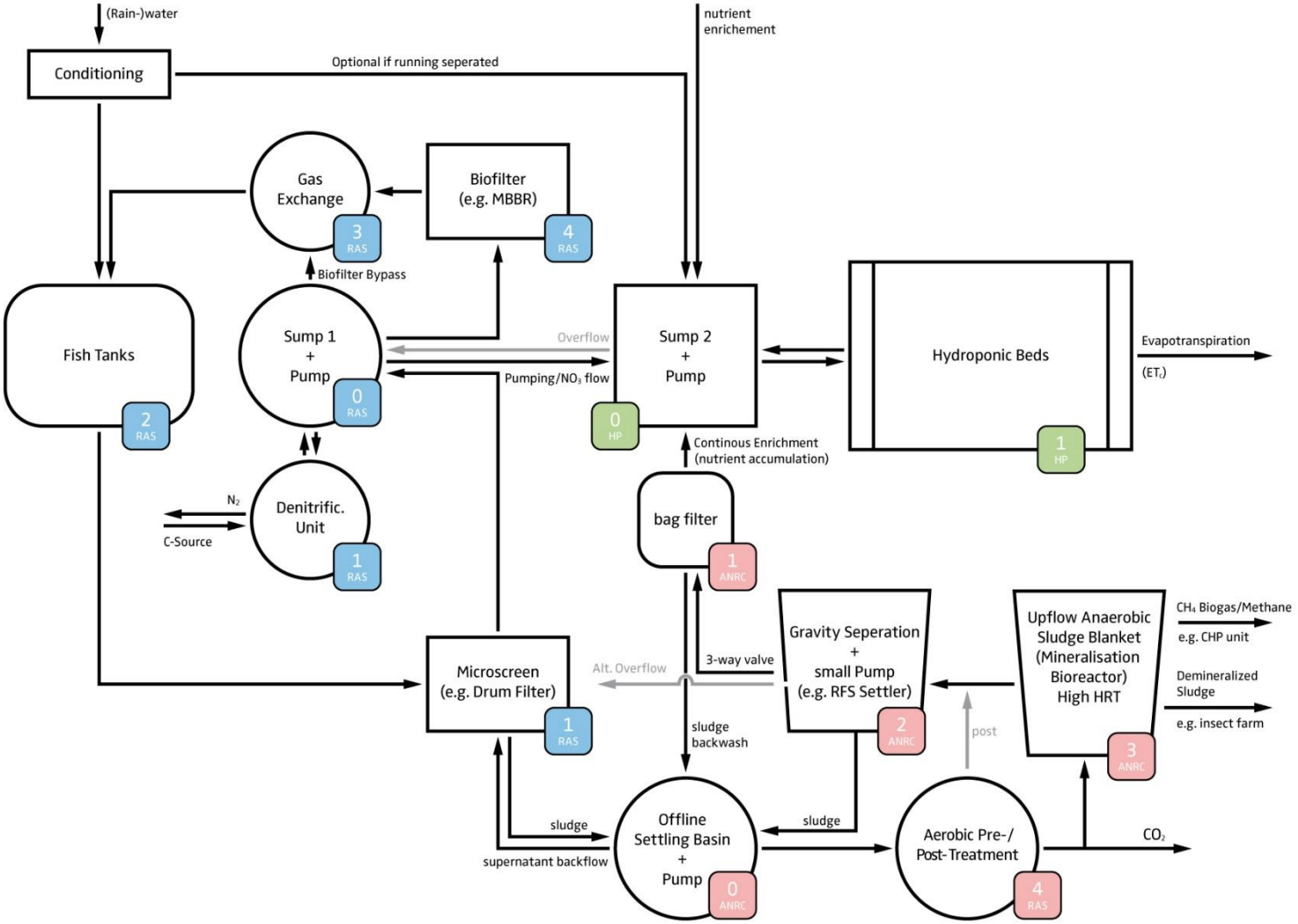






getSRTsludge
addedSludgeSRTdaysago
HRT_days
TSSreduction
SRT_days
Remineralization
maxTotSludge
maxAddedSludge

Potential System Layout of Three-Loop Systems



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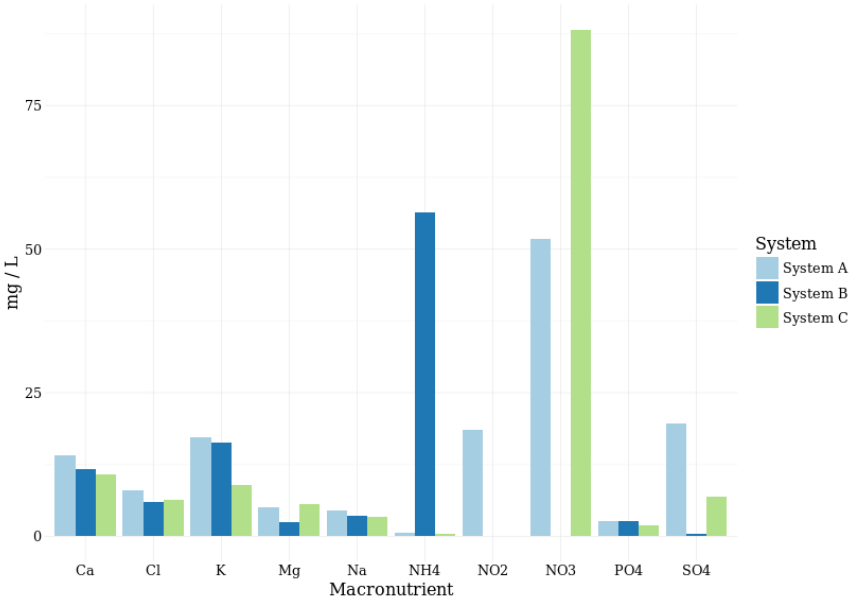
Goddek et al. (2016; in peer review)

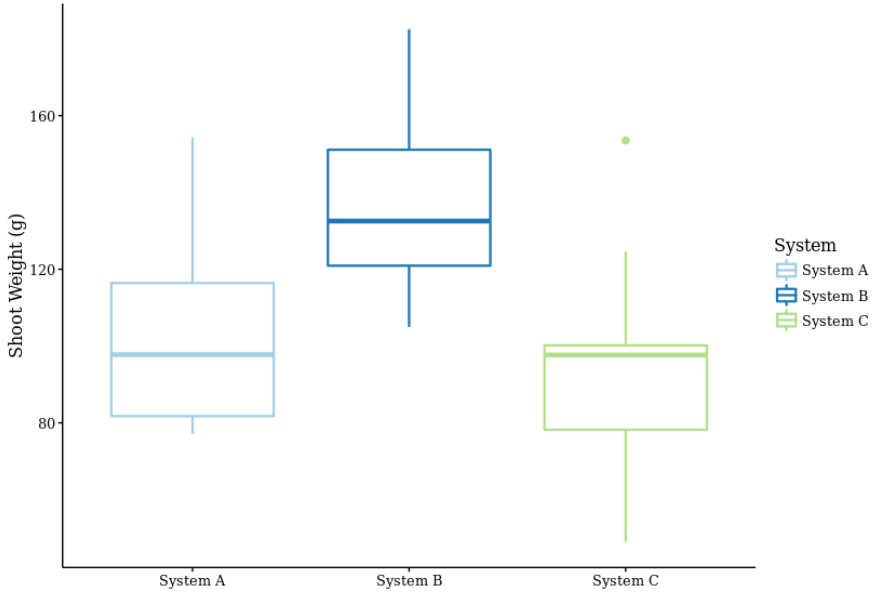
Key Advantages of Three-Loop Systems #1

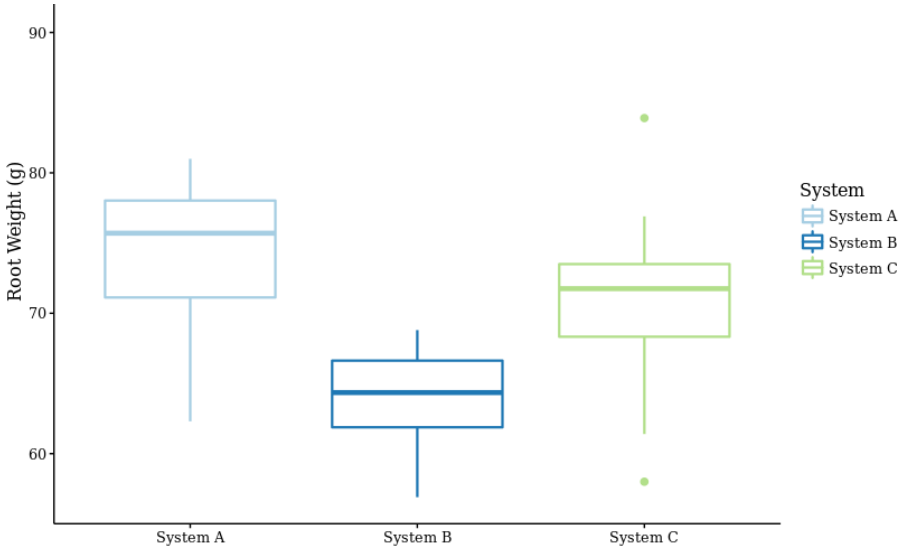
- No more trade-off with respect to water quality
  - Best conditions for both fish and plants
  - Rearing of sensitive fish species (e.g. trout, pike-perch) will be more feasible.
  - N/P and economic model currently under development
- Increased plant growth (>30%) has been observed (Delaide et al., 2016; in submission)

Key Advantages of Three-Loop Systems #2

- Pure anaerobic effluents showed positive impact on plant growth in highly aerated HP units (Goddek et al., 2016; in work)
- Improved sludge treatment efficiency & less dilution of nutrient-rich effluents







Sludge P-Content

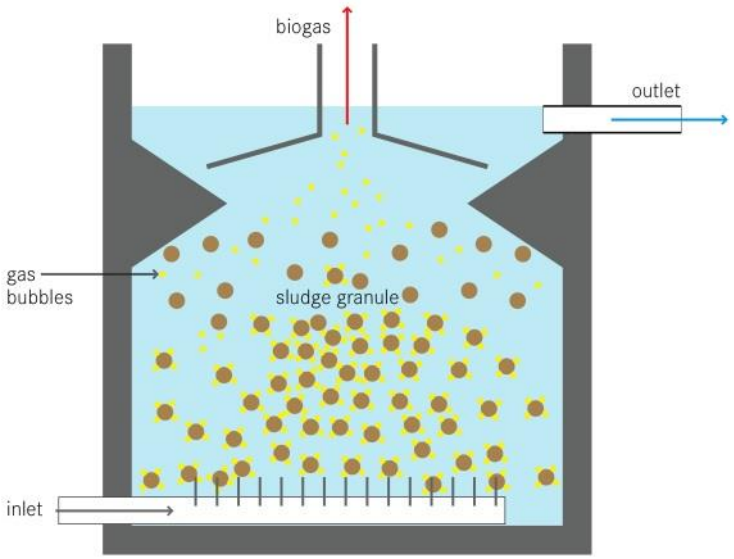
	N (%)	P (%)	N (%)	P (%)
	Neto and Ostrensky (2013)		Personal observations	
Feed	100	100	100	100
Fish retention	35	28	35-50	60-70
Water (Soluble Excretion)	33	17	20-30	5-10
Total Sludge	31	**55**	15-25	35-45
Thereof non-consumed feed	18	18	5-10	5-10
Thereof faeces	13	37	10-15	30-35

Current Practices of Sludge Treatment

- Sewage discharge
  - ECF Farmsystems Berlin
- Aerobic Treatment in one-loop systems
  - Considerably low efficiency
  - Enhanced bacteria growth leads to more (sludge) biomass and loss of macronutrients (N, P)
  - Dilution in the whole system
    - Fish exposed to remineralized nutrients
    - Plants profit less
  - Advantage: CO2 production
    - Good for greenhouse production

Chance: Anaerobic Digestion

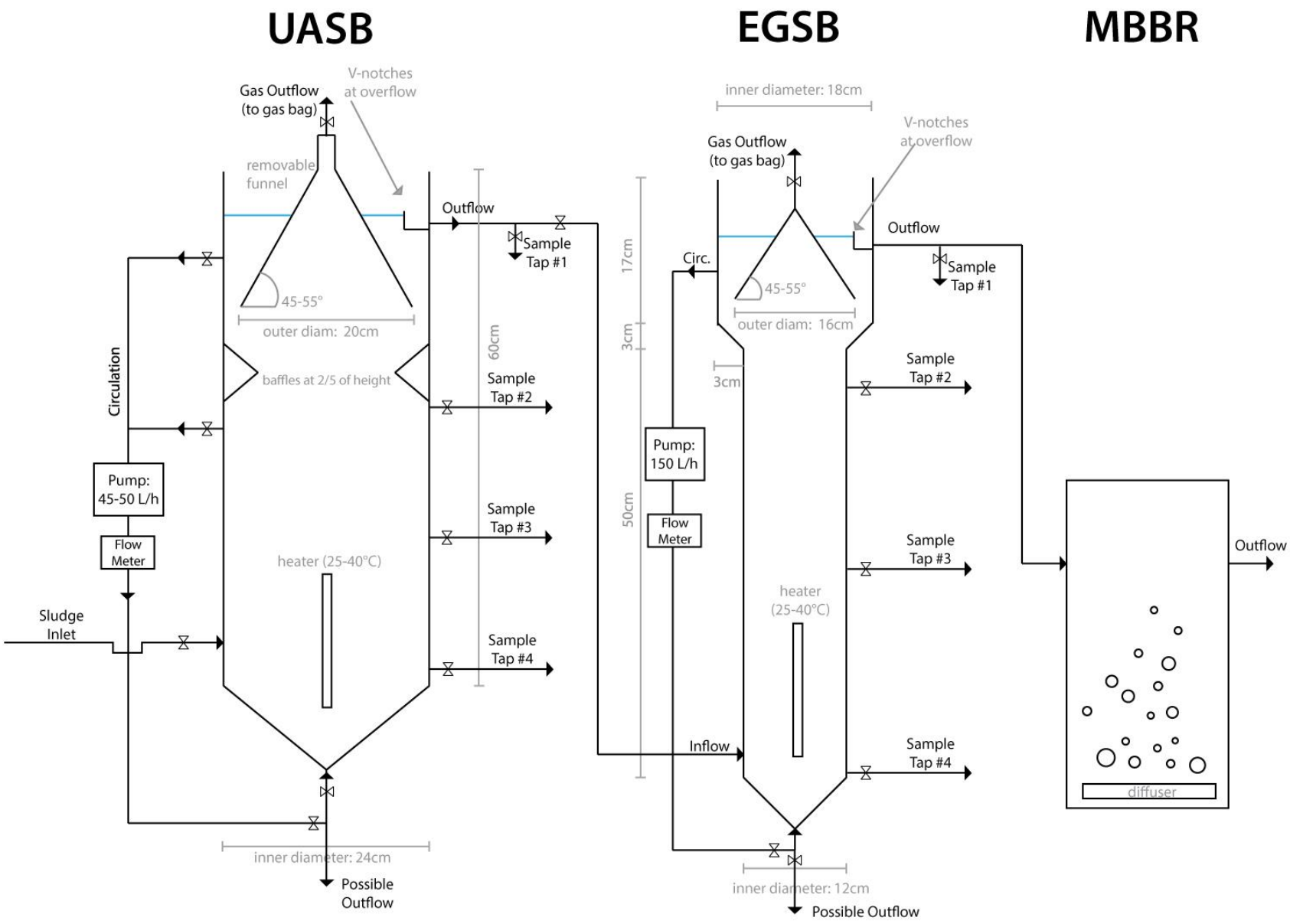
- Methane Production (CHP: Electricity & Heat)
- High TSS (i.e. remineralization) & COD reduction
- C_2-C_6 Volatile Fatty Acids (VFS) are created and reduced
  - The higher the HRT, the higher the reduction
- VFS, COD & TSS are limiting factors of plant growth



Anaerobic Nutrient Remineralization Component #1

- Upflow Anaerobic Sludge Blanket Reactor (UASB)
  - Up to 90% TSS and COD removal
  - Methane Production
  - Low VFS Outflow
- Expended Granular Sludge Bed Reactor (EGSB)
  - Additional reduction of TSS, COD and VFS
  - Additional Methane Production
- Moving Bed Biofilm Reactor (MBBR)
  - Almost total COD, VFS, and TSS removal.
  - Important Oxidization of H_2S to SO_4

Anaerobic Nutrient Remineralization Component #2



Conclusions

- Anaerobic nutrient remineralization best option to close the cycle to a high degree (for nutrients and water).
  - Alternative NH_4 input could be beneficial
  - Anaerobic zone before HP inflow?
  - Short HRT in aerobic sludge post-treatment?
- Optimal growth conditions for fish and plants and possibility to rear sensitive fish species
- Current research results are promising that AP production could have the potential to be higher than HP production

Thx for your attention!

Questions?

Yes?

No?

Maybe?