KÄPPALA

För renare sjöar och skärgård

Temperature transition from mesophilic to thermophilic anaerobic digestion and control of the experimental data against the ADM1 model

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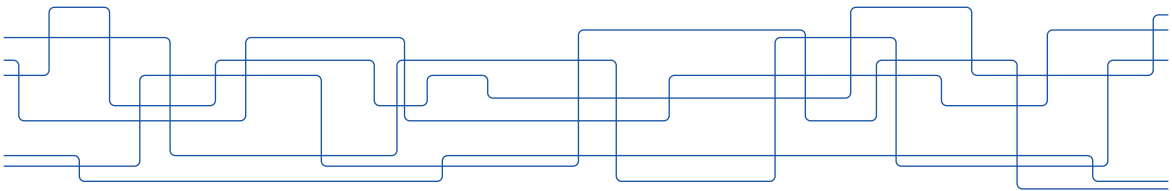
NORDIWA 2021, 17th Nordic Wastewater Conference, September 28 – October 1



Käppala Association

- Operates Käppala WWTP which is co-owned by 11 municipalities in Stockholm, Sweden.
- Treats wastewater from close to 600 000 population equivalents (PEs).
- Resource recovery: biogas, heat, and nutrients.

Case

- PS and WAS stabilized by mesophilic AD.
- Current sludge treatment capacity sufficient until 2035.
- Possible to optimize the process to expand capacity?

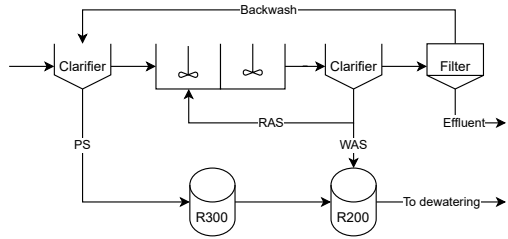


Figure: Sludge streams at Käppala.

Thermophilic AD

Possible benefits

- Faster kinetics.
  - Shorter HRT.
  - Increased biogas production.
- Hygienizing effect.

Possible drawbacks

- More sensitive operation.
- Hard-to-dewater digestate.
- Increased heating demand.

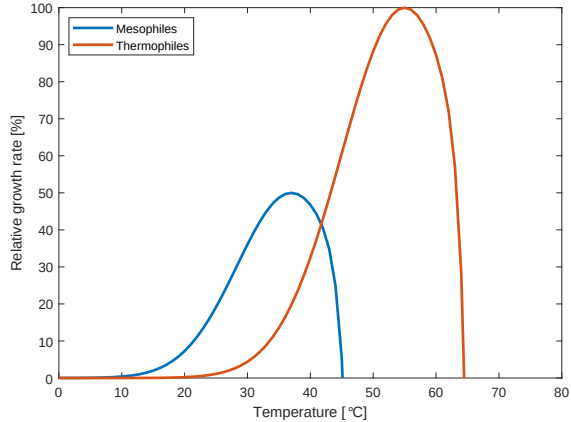


Figure: Temperature dependency of growth rate.

Pilot plant

Target parameters

- Liquid volume: $5\,\mathrm{m}^3$.
- Temperature: $55\,^\circ\mathrm{C}$.
- HRT: $18\,\mathrm{d}$.
  - OLR: 2–2.5 $\mathrm{kg_{VS}\,m^{-3}_{digester}\,d^{-1}}$.
- Substrate: $65\,\%_{\mathrm{mass}}$ PS, $35\,\%_{\mathrm{mass}}$ WAS.

Note

No 1:1 comparison to full-scale available.

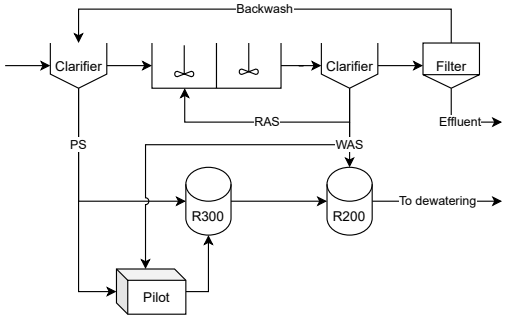


Figure: Pilot in relation to Käppala.

Process modeling

- ADM1.
  - Original model[1] with improvements[2].
- Substrate characterization.
  - Fractionation scheme[3].
- Steady-state simulation of thermophilic pilot process.

[1] IWA Task Group for Mathematical Modelling of Anaerobic Digestion Processes, *Anaerobic Digestion Model No.1 (ADM1)*, IWA Publishing, London, **2002**.

[2] C. Rosén, U. Jeppsson, *Aspects on ADM1 Implementation within the BSM2 Framework*, TEIE 7224, Department of Industrial Electrical Engineering and Automation, Lund Institute of Technology, **2005**.

[3] M. Arnell, S. Astals, L. Åmand, D. J. Batstone, P. D. Jensen, U. Jeppsson, *Water Research* **2016**, 98, 138–146.

Results: Process load and control

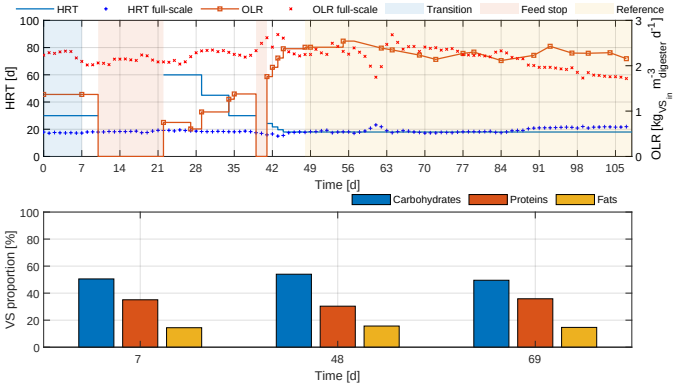


Figure: HRT, OLR, macronutrient inventory.

- Attempted to load process through acclimatization.
- Pump failure interrupted feeding twice.
- HRT/OLR representative to full-scale.
- VS composition fairly constant, high protein from WAS.

Results: Process response to changed conditions

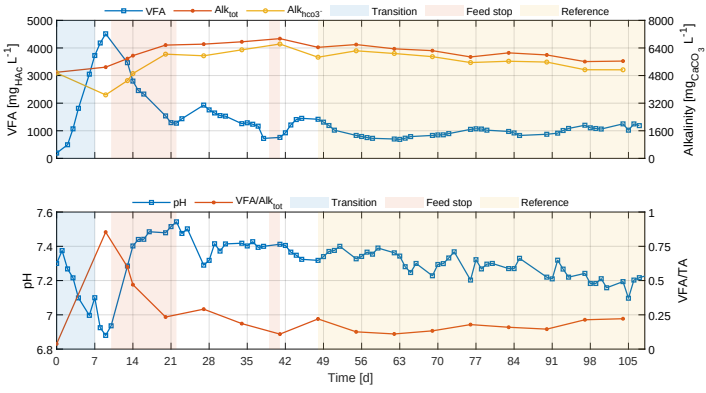


Figure: VFA, alkalinities, pH.

- Serious accumulation of VFA at temperature transition.
- High alkalinity manages to keep the pH relatively stable.
- Stabilization after temporary feeding stop.
- Unsteady "steady-state" around 1000 mg / L.

Results: VS destruction

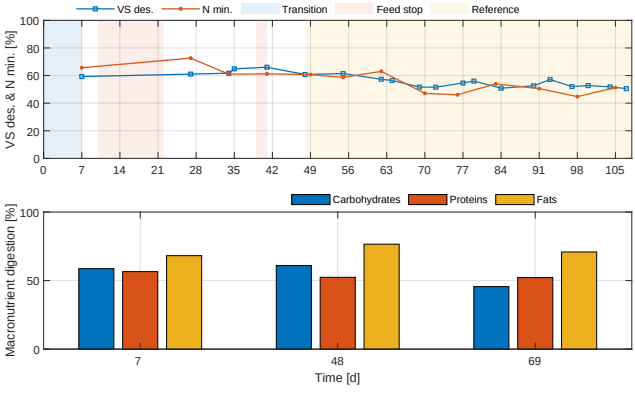


Figure: VS destruction, nitrogen mineralization.

- Initial results are misleading as the digestion chamber mostly contains inoculum.
- However, indicates that WAS benefits from pre-digestion.
- Destruction of proteins more efficient compared to mesophilic pilot (cf. mean destruction: 36 %).

Results: Biogas production

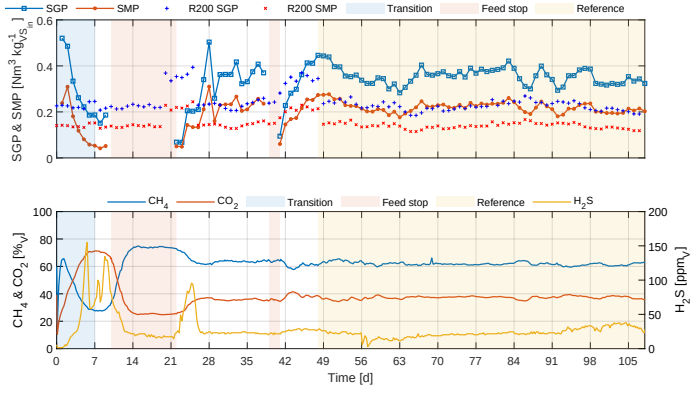


Figure: Specific gas/methane production and gas composition.

- Sharp decline in gas production at the temperature transition.
- In reference operation, the pilot and R200 have a similar trend.
- Sulfate-reducing organisms benefit from inhibited methanogens.
- Recovery begins just before feeding stop.

Results: Summary

	Pilot	R200	Full-scale
VS destruction [%]	54.5 ± 3.4	21.7 ± 3.1	57.0 ± 1.5
SMP [$\mathrm{Nm^3_{CH_4}\,kg^{-1}_{VS}}$]	0.221 ± 0.023	0.141 ± 0.015	0.317 ± 0.018
CH_4 [%]	61.9 ± 1.2	$62^{\dagger}$	–
pH	7.28 ± 0.07	7.27 ± 0.05	–
VFA [$\mathrm{mg_{HAc}\,L^{-1}}$]	982 ± 187	119 ± 9	–
$\mathrm{Alk_{tot}}$ [$\mathrm{mg_{CaCO3}\,L^{-1}}$]	6097 ± 346	5014 ± 198	–
$\mathrm{Alk_{hco3^-}}$ [$\mathrm{mg_{CaCO3}\,L^{-1}}$]	5679 ± 382	4952 ± 187	–

Experimental results given as mean value $\pm$ standard deviation.

†Assumed value in production.

Results: Simulation

	HRT 1		HRT 2	
	Sim.	Exp.	Sim.	Exp.
CH_4 [%]	62.3	62.6 ± 1.3	62.3	62.0 ± 0.9
CO_2 [%]	36.3	36.7 ± 1.1	36.0	37.3 ± 0.9
SGP [$Nm^3\,kg^{-1}_{VS_{in}}$]	0.385	0.356 ± 0.049	0.390	0.371 ± 0.024
SMP [$Nm^3_{CH_4}\,kg^{-1}_{VS_{in}}$]	0.240	0.223 ± 0.032	0.243	0.230 ± 0.013
VS destruction [%]	42.0	58.9 ± 2.5	40.9	52.9 ± 2.2
pH	7.32	7.34 ± 0.04	7.35	7.29 ± 0.04

Experimental results given as mean value $\pm$ standard deviation.

Conclusions

- The thermophilic process could not surpass the current mesophilic two-step process.
  - Lower VS destruction, lower SMP, equivalent methane content, jittery process dynamics.
- It is possible to convert a mesophilic process to a thermophilic one without major problems.
- Proteins are digested more efficiently in thermophilic conditions.
- Several results could be predicted through simulation with relatively little preparation.

Future work

- Examine shorter residence times (stress test).
- Examine pre-treatment of WAS.
- Examine the hygienizing effect of the thermophilic process.

Thank you for listening!