



Anaerobic digestion of sludge from pulp and paper mill -Laboratory studies

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Introduction

- Forest industry spread around the world
- Activated sludge process a typical technology to treat wastewater
 - Biosludge 2900-4000 tTS/mill
- Sludge treatment up to 50–60 % of wastewater treatment costs
- After decline in number of paper mills e.g. Finland is again investing to forest industry based biorefinerys



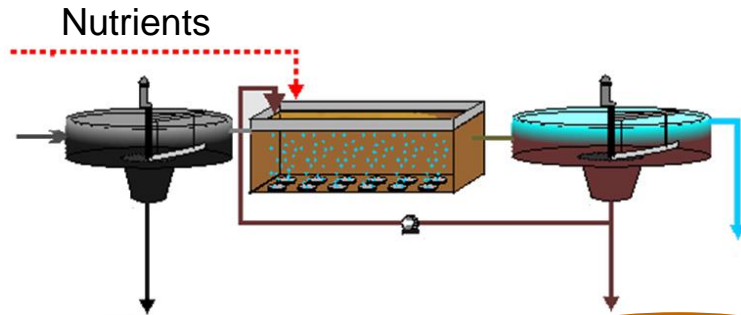
Planned new pulp mills (EPN 2015)

Objectives

1. Determine the long-term (400 days) performance of pulp and paper industry biosludge in mesophilic anaerobic digestion
2. Improve the digestibility and methane yield of biosludge using thermal pretreatment at 121°C
3. Compare mesophilic and thermophilic digestion
4. Produce nutrient media for downstream microalgae cultivation (digestate centrate)



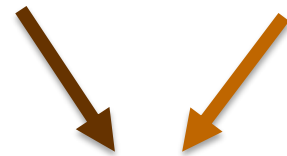
Materials & Methods



Primary sludge
2 batches

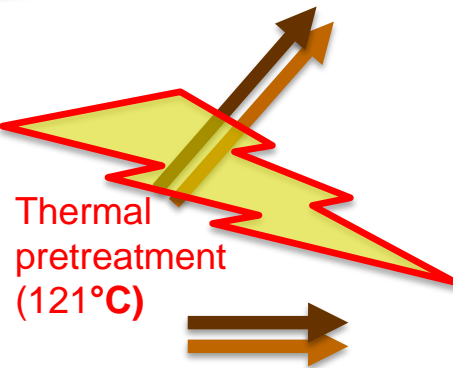
Biosludge
9 batches collected
over a year

Unsettled (TS 1.5%)
Settled (TS 4%)



Characterization

- TS, VS
- COD
- Nitrogen
- Phosphorus

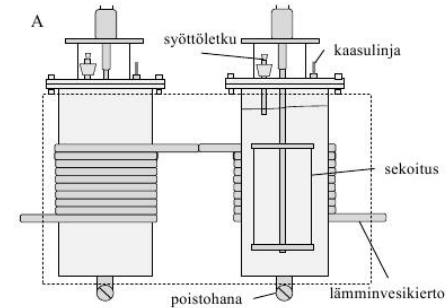


Thermal
pretreatment
(121°C)



BMP assays (35°C)

- 120 ml bottles
- $7.9 \text{ VS}_{\text{subst}} / 16 \text{ VS}_{\text{inoc}} \cdot 0.5 \cdot 4$



Reactor trials

- CSTRs 6 L (5 L liquid) at 35°C
- Biosludge 3 parallel reactors
- Bio+Primary sludge 1 reactor
 - Mix ratio 1:1 TS
- Duration 400 days

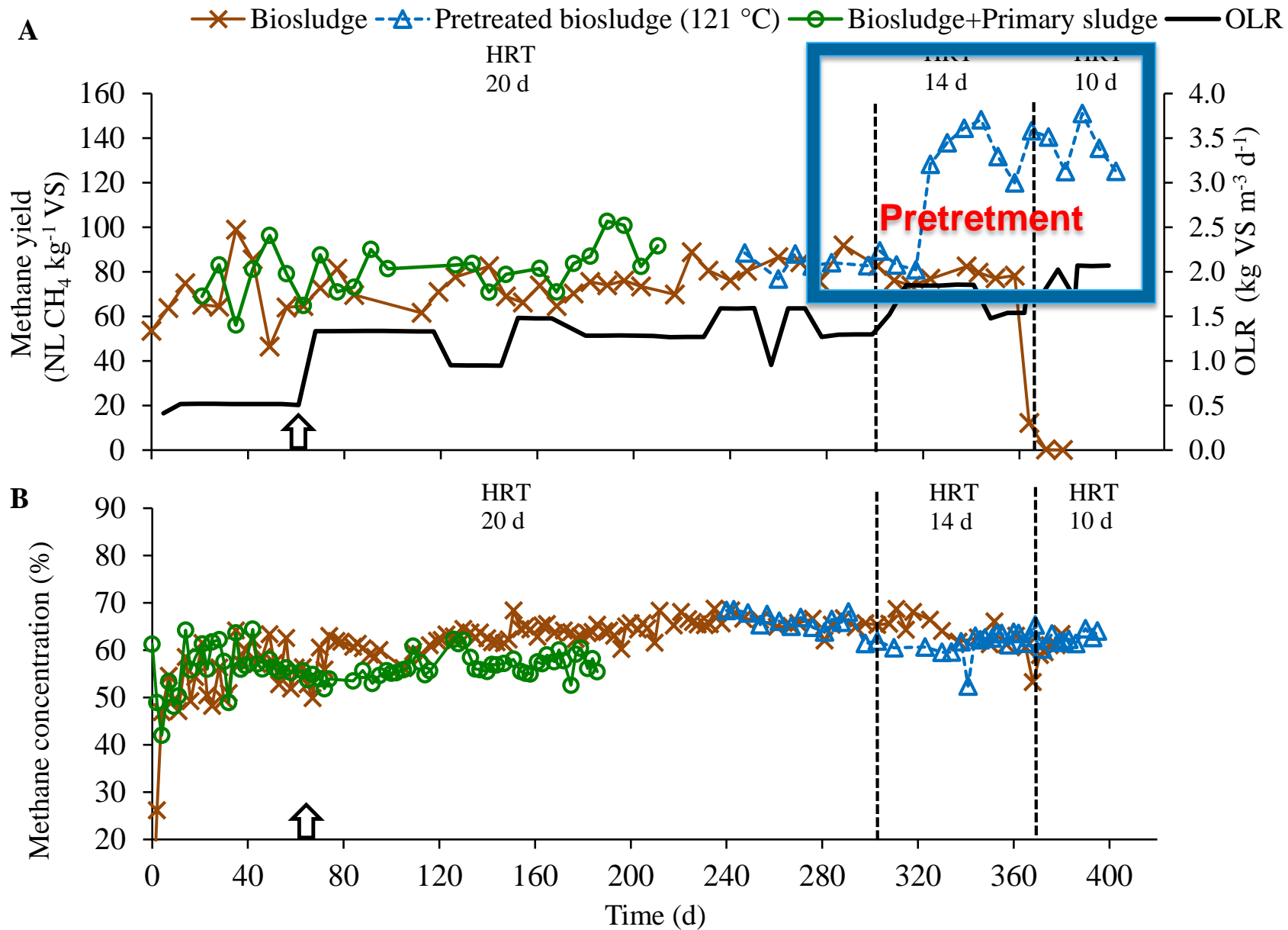


Results - sludge characteristics and methane yields

Table 1. Substrate characteristics

	Unsettled Biosludge	Settled Biosludge	Pretreated Biosludge	Primary Sludge
TS (%)	1.3 (1.1–1.5)	3.7 (2.5–4.3)	4.1 (0.1) ^a	4.8 (3.0–6.5)
VS (%)	0.9 (0.7–1.0)	2.7 (1.8–3.2)	2.9 (0.1) ^a	3.0 (2.0–4.0)
VS/TS (%)	70 (65–71)	73 (68–78)	70 (0.1) ^a	64 (62–67)
TKN (g kg ⁻¹ TS)	81 (3) ^a	63 (44–81)	51 ^a	4 (4–4)
P _{tot} (g kg ⁻¹ TS)	n.m.	1.2–8.6	n.m.	n.m.
Lignin (% of TS)	44 (5)	44 (5)	n.m.	n.m.
BMP ₃₅ (L CH ₄ kg ⁻¹ VS ⁻¹)	93 (3.7) ^a	90 (89–102)	124 (7) ^a	127 (3.3) ^a
BMP ₃₅ (L CH ₄ kg ⁻¹ ww ⁻¹)	0.6 (0.1) ^a	2.4 (1.6–2.5)	2.8 (0.1) ^a	3.9 (0.1) ^a





Results – digestate characteristics

	Unsettled Biosludge	Settled Biosludge	Pretreated Biosludge	Bio+Primary Sludge
VFA (g L ⁻¹ as SCOD)	<0.1	<0.1	<0.1	<0.1
SCOD (g L ⁻¹)	0.7 (0.1)	0.6 (0.1)	1.4 (0.1)	0.6 (0.1)
TKN (g kg ⁻¹ TS)	44 (5)	44–65	58–59	27 (4)
NH ₄ -N (mg L ⁻¹)	170	210-590	486-496	90-160
P _{tot} (g kg ⁻¹ TS)	n.m.	6.7–8.0	n.m.	n.m.
Lignin (% of TS)	n.m.	46	n.m.	n.m.
VS-removal (%)	9	9-10	19–25	36



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Cultivation of *Nannochloropsis* for eicosapentaenoic acid production in wastewaters of pulp and paper industry



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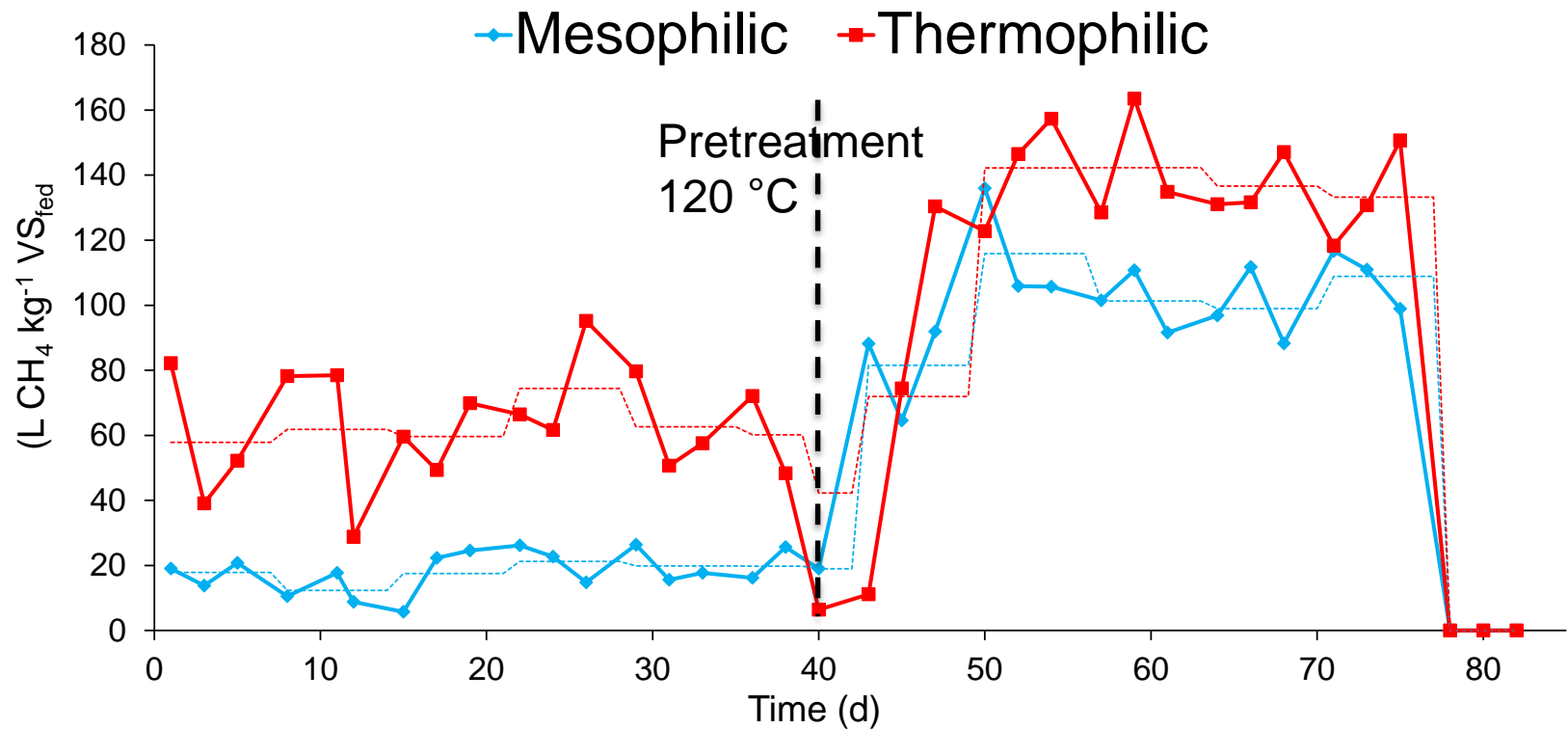


Preliminary energy balance estimation

	TS 1.3%, HRT 14 d		TS 4%, HRT 14 d		TS 4%, HRT 10 d
	Untreated	121°C	Untreated	121°C	121°C
Biosludge temperature 14°C					
$E_{i,heat}$ (MWh a ⁻¹)	7215	11291	2430	3761	3706
$E_{i,electricity}$ (MWh a ⁻¹)	449	449	146	146	117
E_o (MWh a ⁻¹)	1764	1764	1940	3478	3478
ΔE (MWh a ⁻¹)	-5900	-9976	-636	-429	-345
E_o/E_i	0.23	0.15	0.75	0.89	0.91
Biosludge temperature 35°C					
$E_{i,heat}$ (MWh a ⁻¹)	578	4655	273	1604	1549
$E_{i,electricity}$ (MWh a ⁻¹)	449	449	146	146	117
E_o (MWh a ⁻¹)	1764	1764	1940	3478	3478
ΔE (MWh a ⁻¹)	737	-3339	1521	1728	1812
E_o/E_i	1.72	0.35	4.6	2.0	2.1



Mesophilic and thermophilic digestion



Conclusions

1. Nutrient and solid content of pulp and paper industry biosludge varied between samples collected within one year – methane yield remained at same level. Between mills also methane yield varies.
2. Thermal pretreatment can increase methane yield, but also allow shorter HRT (10 d)
3. Thermophilic process produces higher methane yield, but after pretreatment the difference compared with mesophilic process is not that clear.



Mesophilic anaerobic digestion of pulp and paper industry biosludge—long-term reactor performance and effects of thermal pretreatment

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On going work related to pulp and paper biorefinerys

- Energy balances; pretreatments (at 80-200°C),
- Integration of pulp mill anaerobic digestion with algae and/or bacteria cultivations to produce high value compounds and energy



Acknowledges and contacts

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Pepe Lindqvist



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EU:lta
2007–2013

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Linked 

Thank you!

