CYPRUS 2016

4th International Conference

on Sustainable Solid Waste Management

Limassol, 23-25/06/2016

Pre- and Intermediate Hybrid Hydrolysis Processes for the Improvement of the Anaerobic Digestion of Waste Activated Sludge

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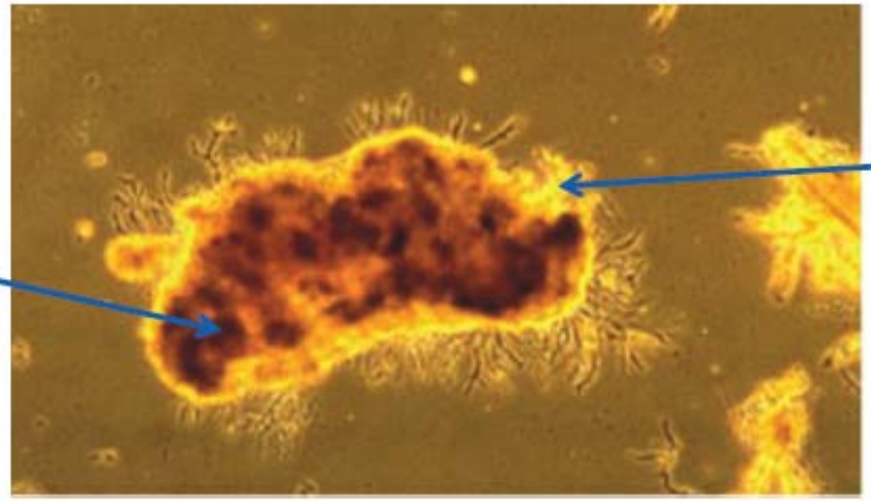
WAS Anaerobic Digestion

Anaerobic digestion (AD) is not completely effective towards WAS because the complexity of the substrate limits the efficacy of the biological process.

Microbial cells, cell walls and membranes in the WAS are strong barriers to the penetration of hydrolytic enzymes.

Also the extracellular polymeric substances (EPS) contained in WAS are believed to be a factor for poor AD of sewage sludge and its subsequent dewatering.

Bacteria
Dark-brown color



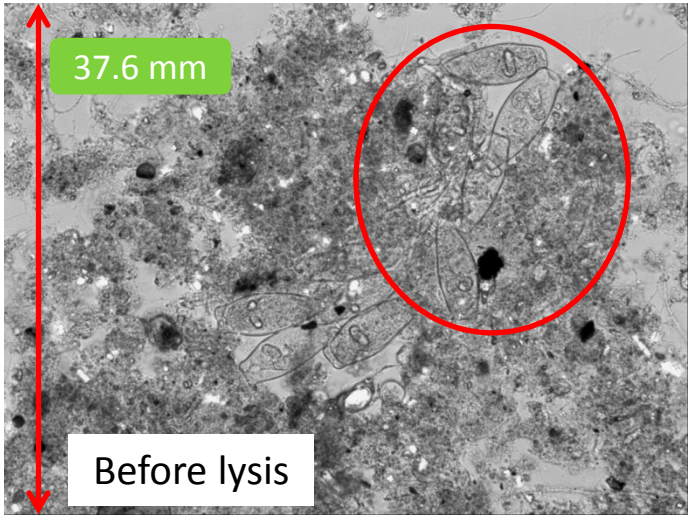
Extracellular Polymeric Substance (EPS)
Glowing color

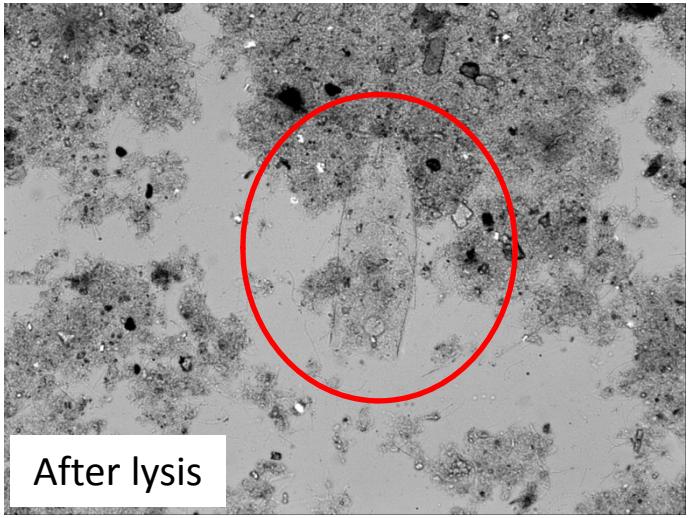
from Shana et al., 2015

WAS Anaerobic Digestion

Pre- or intermediate treatments

Mechanical
Chemical
Thermal
Biological
or a combination of them





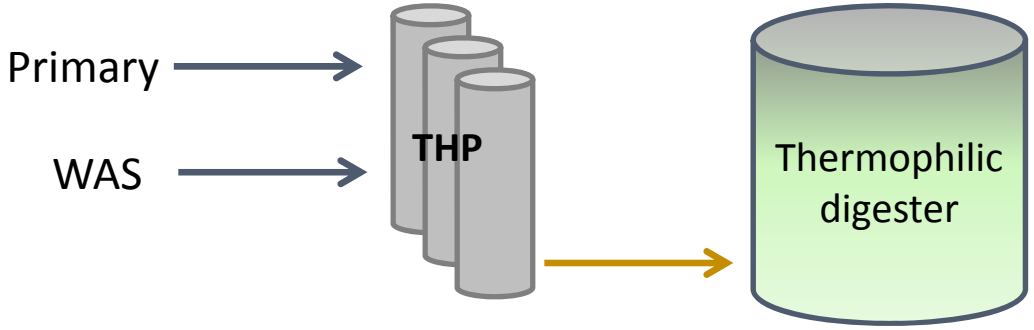
from Ruffino et al., 2013

Pre vs. Intermediate Treatments

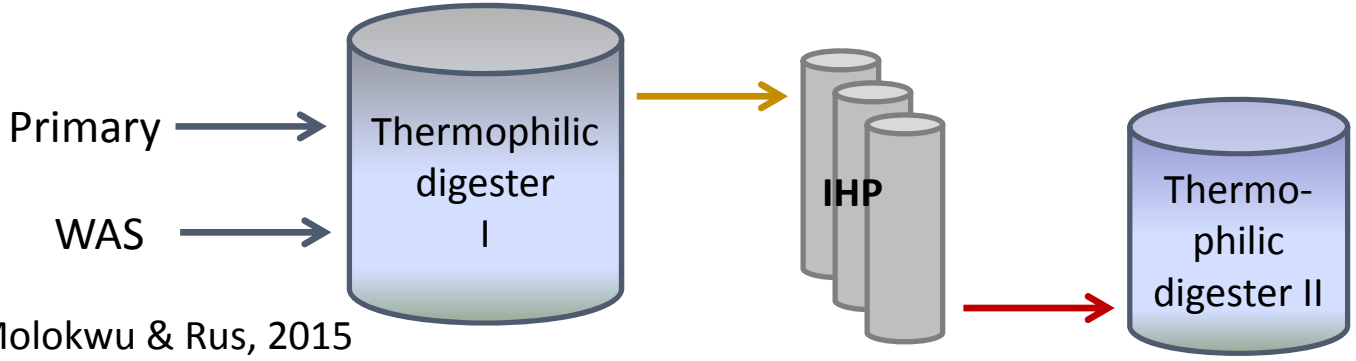
Pre- or intermediate treatments

THPs, thermal hydrolysis processes (Cambi, Veolia, and Haarslev) (160-165°C, 6 bar, 30 minutes) → positive impact on solid de-waterability and rheology.

CONVENTIONAL THP



IHP, INTERMEDIATE HYDROLYSIS PROCESS



Adapted from Molokwu & Rus, 2015

Pre vs. Intermediate Treatments State of the Art

Author	Operating conditions	Results
Nielsen et al. (2011)	80°C, 10-24-48 h 130°C-170°C autoclave, 15 min 170°C, pH 10 KOH, 15 min	+2% CH_4 (pre-HP) +28% (IHP)
Takashima and Tanaka (2014)	25, 100, 180°C pH 2, 4 and 6 (HCl) 1 hour	good performances in organic matter destruction and methane production
Li et al. (2013)	Extraction of sludge from semi-cont digester 0.1 mol/l NaOH 30, 60, 90, 120 min	+ 33% biogas (vs. untreated)
Zhang et al. (2016)	already anaerobically digested sludge samples FNA i.e. HNO_2, 0.77 – 3.85 mg N/l for 24 h	+ 40% methane at 0.77 mg N/l (vs. untreated)

Materials and Methods

WAS Sample → Pre-Treatments

Castiglione Torinese SMAT WWTP
2,300,000 e.i.

Alkali agents
$NaOH$ - $Ca(OH)_2$
Doses
4-8 g alkali/ 100 g TS
Contact time
90 min
Temperatures
20 - 70 - 90°C

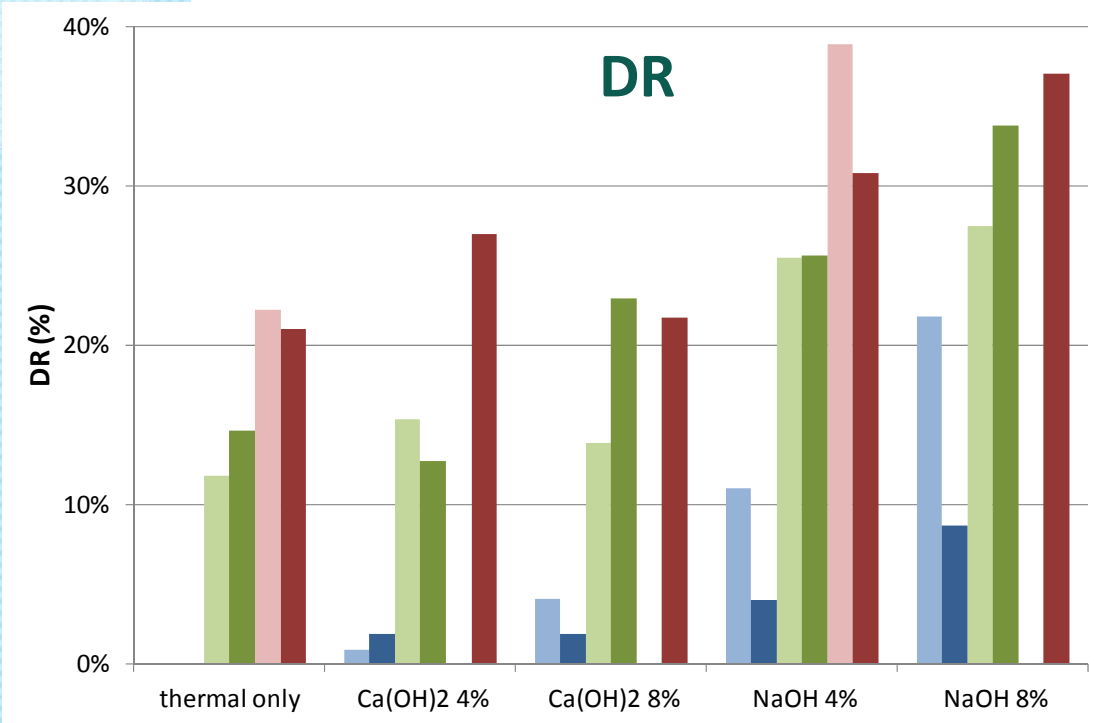
15 tested operating conditions

Anaerobic Digestion tests

Batch, mesophilic
Substrate : inoculum = 1.6

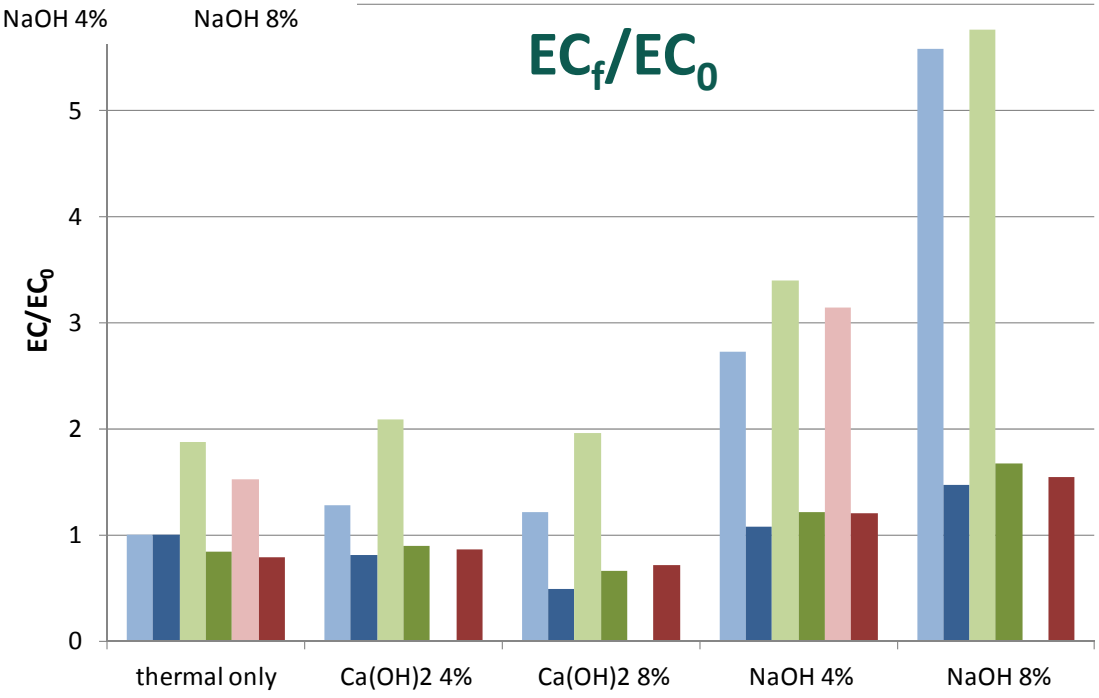
Digestate sample → Intermediate Treatments

Results I



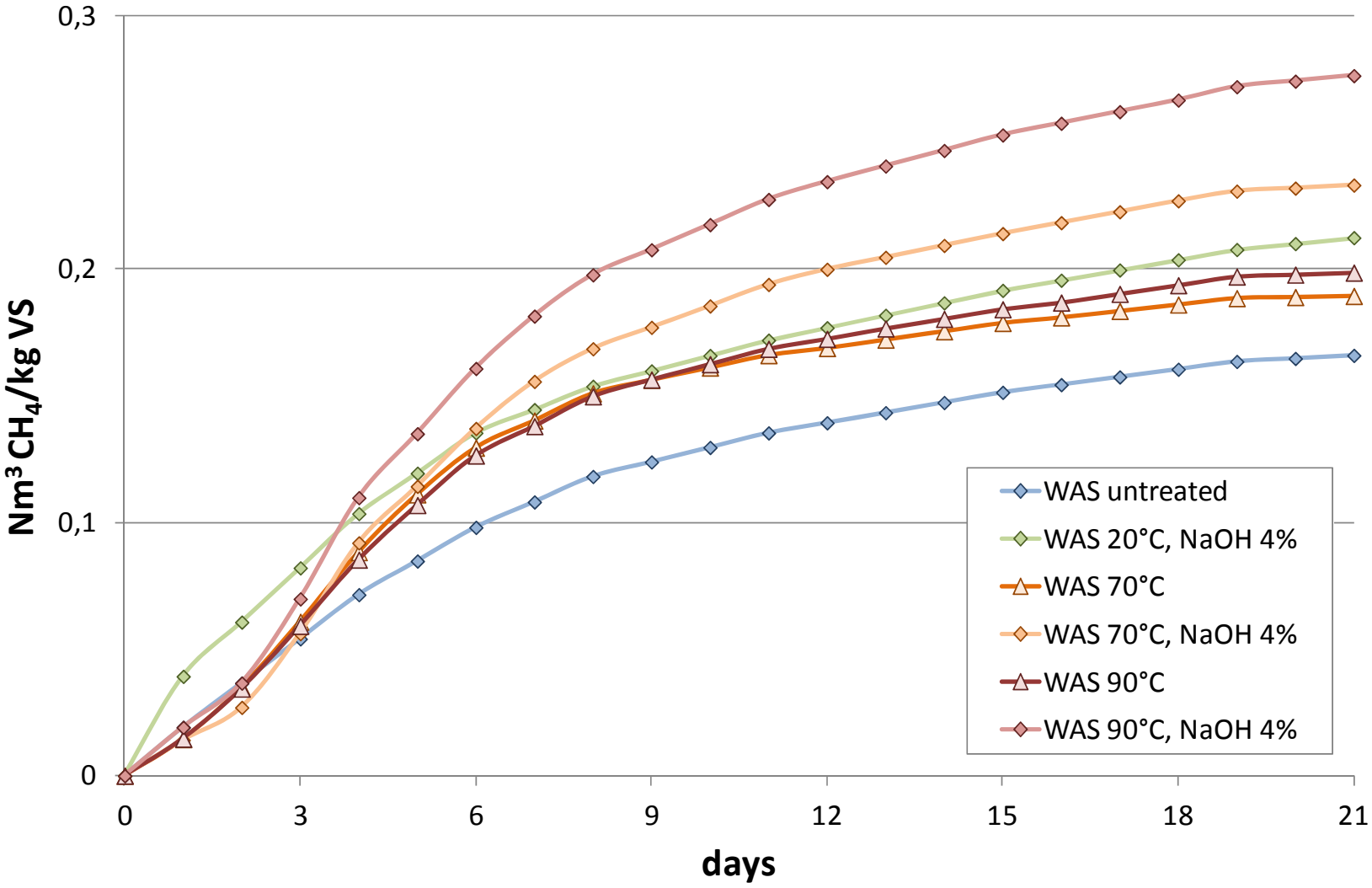
Disintegration Rate (DR)

$$\frac{SCOD_{lys} - SCOD_0}{COD_{tot} - SCOD_0} \cdot 100\%$$

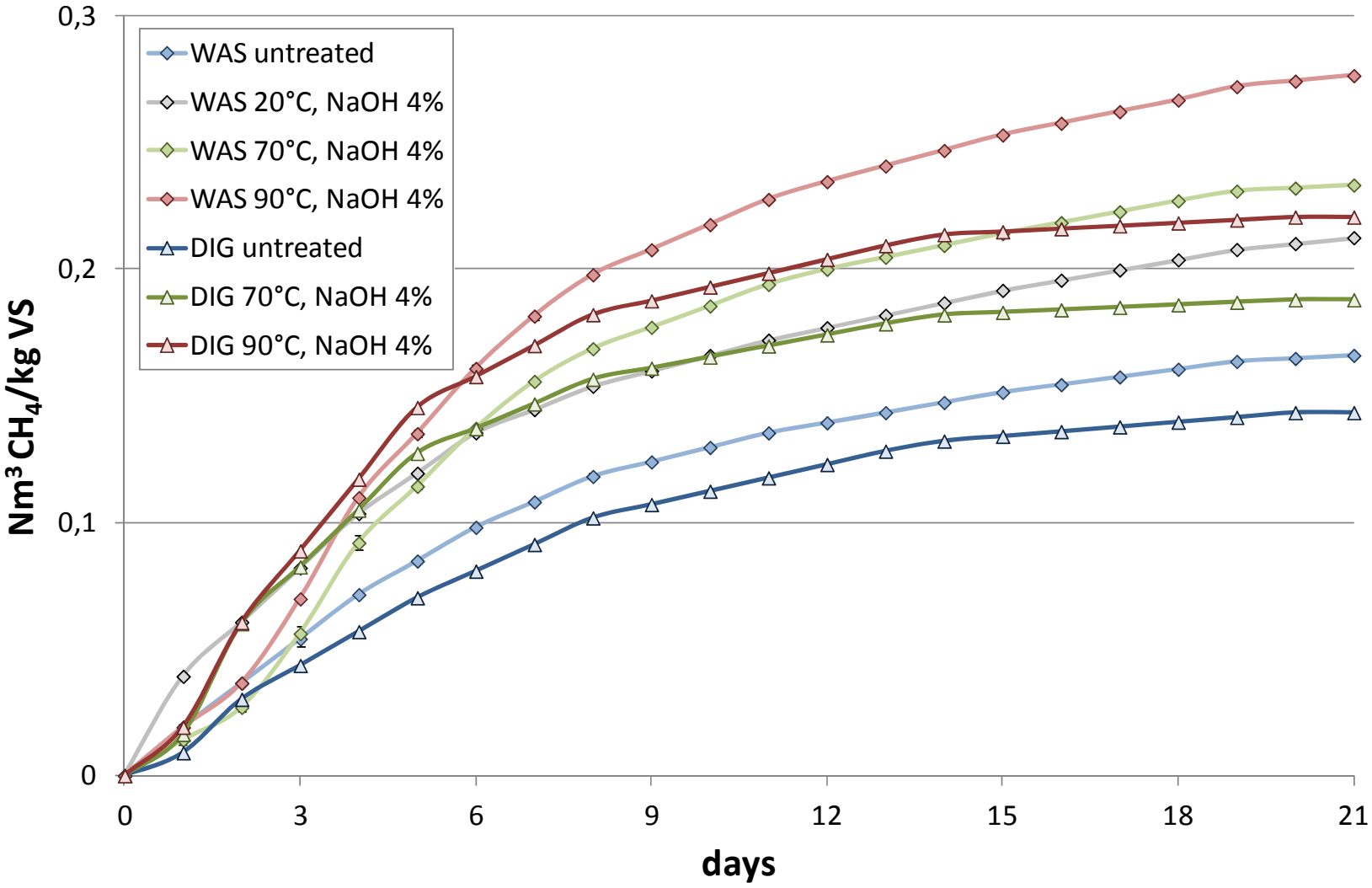


- WAS 20°C
- Digestate 20°C
- WAS 70°C
- Digestate 70°C
- WAS 90°C
- Digestate 90°

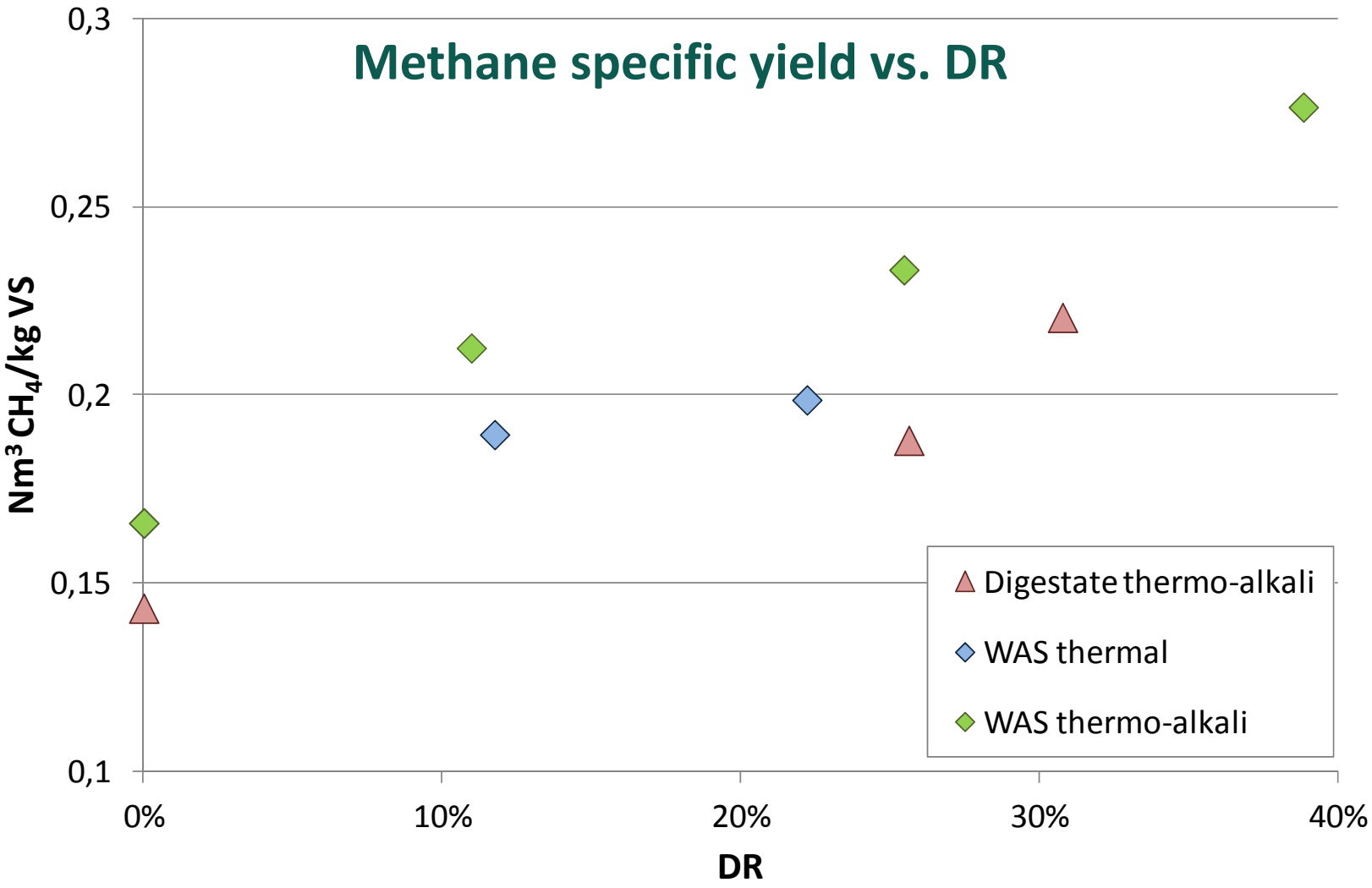
Results II


0,3
0,2
0,1
0
Nm³ CH4/kg VS
0
3
6
9
12
15
18
21
days
WAS untreated
WAS 20°C, NaOH 4%
WAS 70°C
WAS 70°C, NaOH 4%
WAS 90°C
WAS 90°C, NaOH 4%

Results III

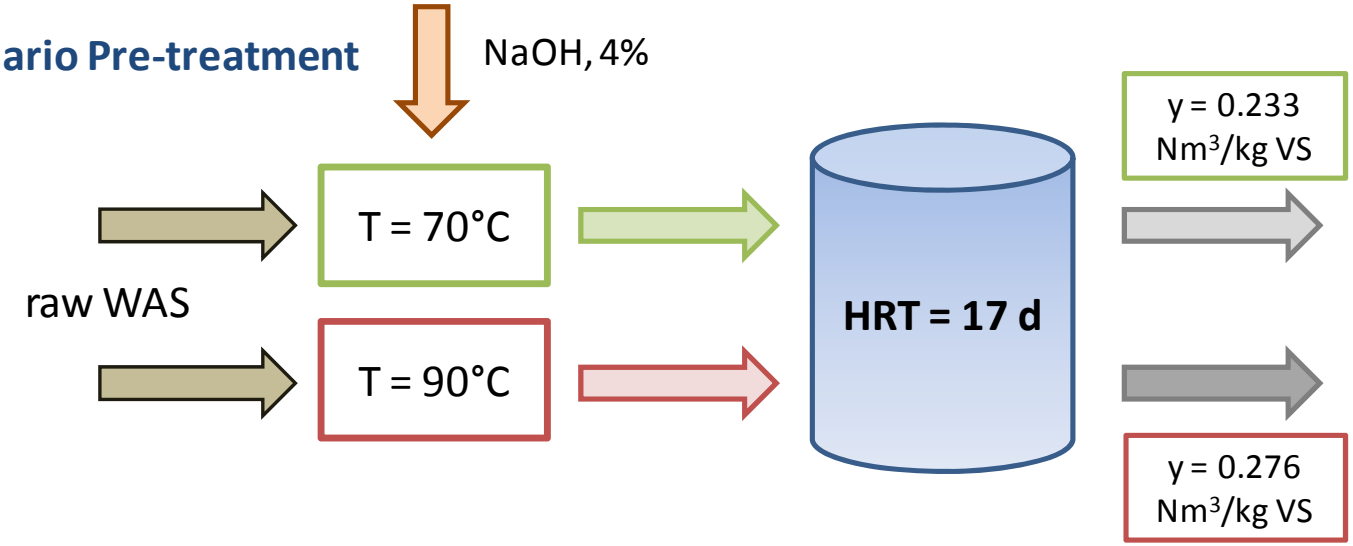

0,3
0,2
0,1
0
Nm³ CH4/kg VS
WAS untreated
WAS 20°C, NaOH 4%
WAS 70°C, NaOH 4%
WAS 90°C, NaOH 4%
DIG untreated
DIG 70°C, NaOH 4%
DIG 90°C, NaOH 4%
0
3
6
9
12
15
18
21
days

Results IV

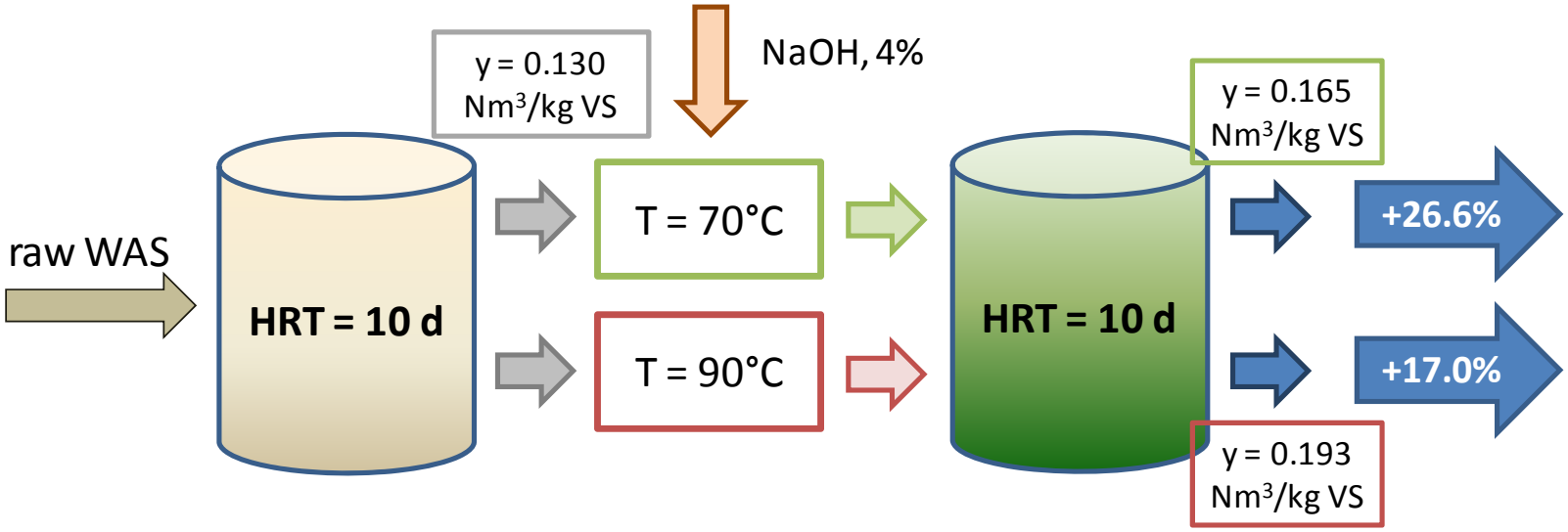

Methane specific yield vs. DR
0,3
0,25
0,2
0,15
0,1
Nm³ CH₄/kg VS
0%
10%
20%
30%
40%
DR
Digestate thermo-alkali
WAS thermal
WAS thermo-alkali

Preliminary assessment for technical and economic evaluation

Scenario Pre-treatment



Scenario Intermediate Treatment



Conclusions

The main results obtained in the experimentation demonstrated that:

- thermal and hybrid treatments were, on average, **more effective on WAS than on digestate**, if the DR parameter is used to evaluate the performance of the treatment;

- for the treatment of both WAS and digestate **NaOH** had to be preferred to $Ca(OH)_2$. The combination with the thermal effect increased the amount of sCOD released;

- the **only-thermal** pre-treatment determined very low increases in methane specific yield if compared to performances of hybrid pre-treatments. Increases were of respectively 14% for the temperature of 70 °C and of 20% for 90 °C. These findings were in line with the results of a previous study(*) carried out on WAS samples collected in the same WWTP;

(*) Ruffino B., Campo G., Genon G., Lorenzi E., Novarino D., Scibilia G., Zanetti M.C. (2015), **Bioresource Technology**, 175, 298-308, DOI: 10.1016/j.biortech.2014.10.071.

(**) Ruffino B., Campo G., Cerutti A., Zanetti M.C., Lorenzi E., Scibilia G., Genon G. (in press), **Waste and Biomass Valorization**, DOI 10.1007/s12649-016-9537-x.

Conclusions

- the results of the digestibility tests carried out on the WAS samples pre-treated with an **hybrid process** (NaOH 4%, 70 °C or 90 °C) showed an increase in the methane specific production of approximately 40% for the sample treated at 70 °C and of more than 66% for the sample treated at 90 °C, compared with the untreated sample (**);

- the sample of untreated **digestate** showed a specific methane yield of 0.143 Nm^3/kg VS, approximately 14% less than the raw WAS. With the hybrid treatment the capacity of producing methane of the digestate increased by 31%, at the temperature of 70 °C, and by 54% at 90 °C;

- a comparison between the two scenarios revealed that the substrate treated with an **intermediate treatment** carried out at 70 °C produces 27% more methane than the same substrate treated with a pre-treatment carried out in the same conditions.

Massimiliano Bolettieri and Simone Morra are gratefully acknowledged for their support in the experimental activities

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Thank you for your attention!

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