10th International Conference on Sustainable Solid Waste Management
Chania, Greece, 21 - 24 JUNE 2023

Evaluation of the optimal sewage sludge pre-treatment technology through continuous reactor operation

G.-C. Mitraka[1,2], K.N. Kontogiannopoulos[1], A.I Zouboulis[2], P.G. Kougias[1]

[1]Soil and Water Resources Institute, Hellenic Agricultural Organization – Dimitra, Thermi, Greece
[2]Laboratory of Chemical & Environmental Technology, Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

@WMBlab @wmb_lab Thermi-Thessaloniki, GR

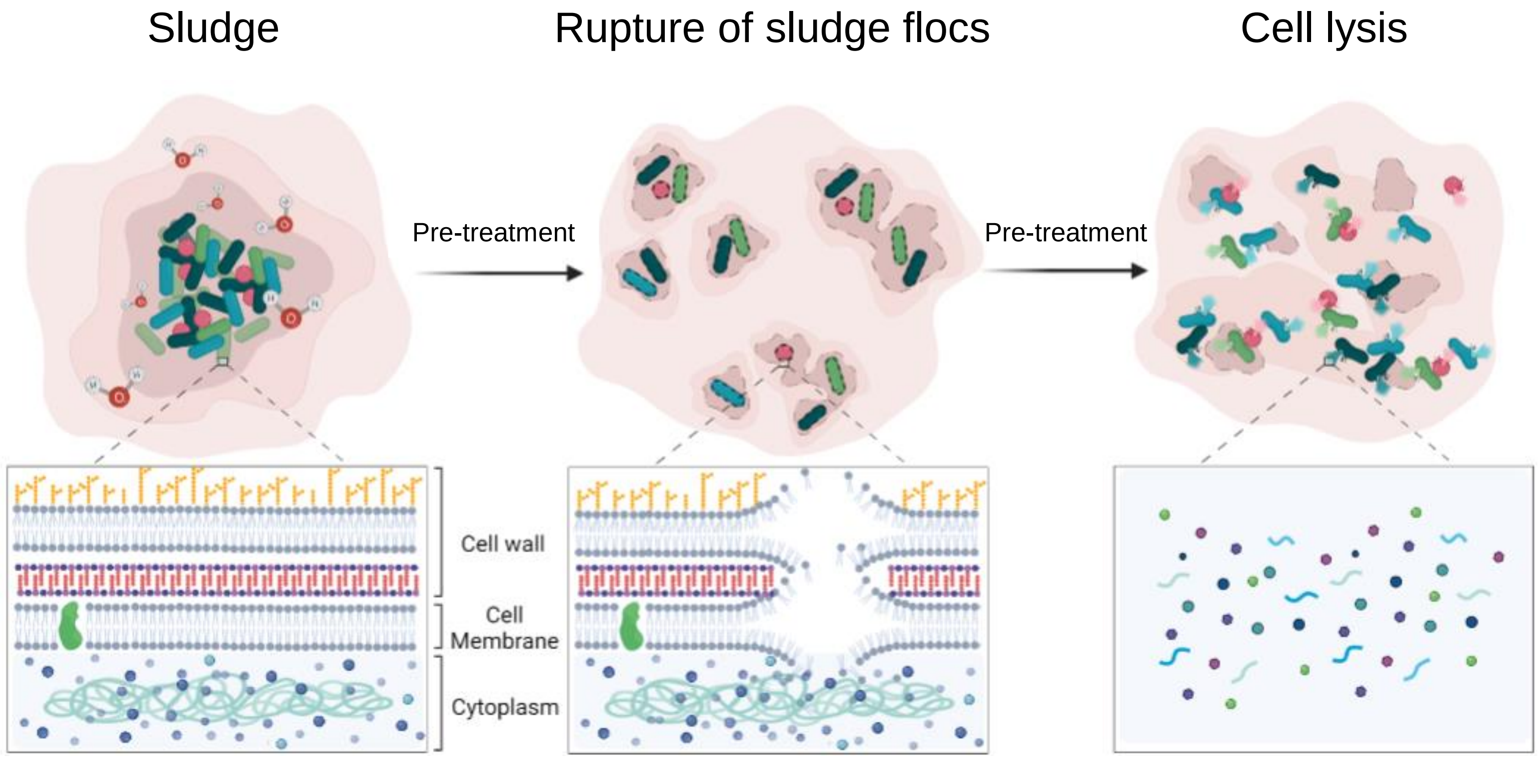
Why is sludge's pre-treatment important?

Pre-treatment's beneficial aspects

- Rupture of sludge flocs
  - Particle size reduction
  - Increased surface area
  - Enhanced hydrolysis
- Rupture of EPS and cell walls
  - Release of intracellular organic substances
  - Increased bioavailability

↓

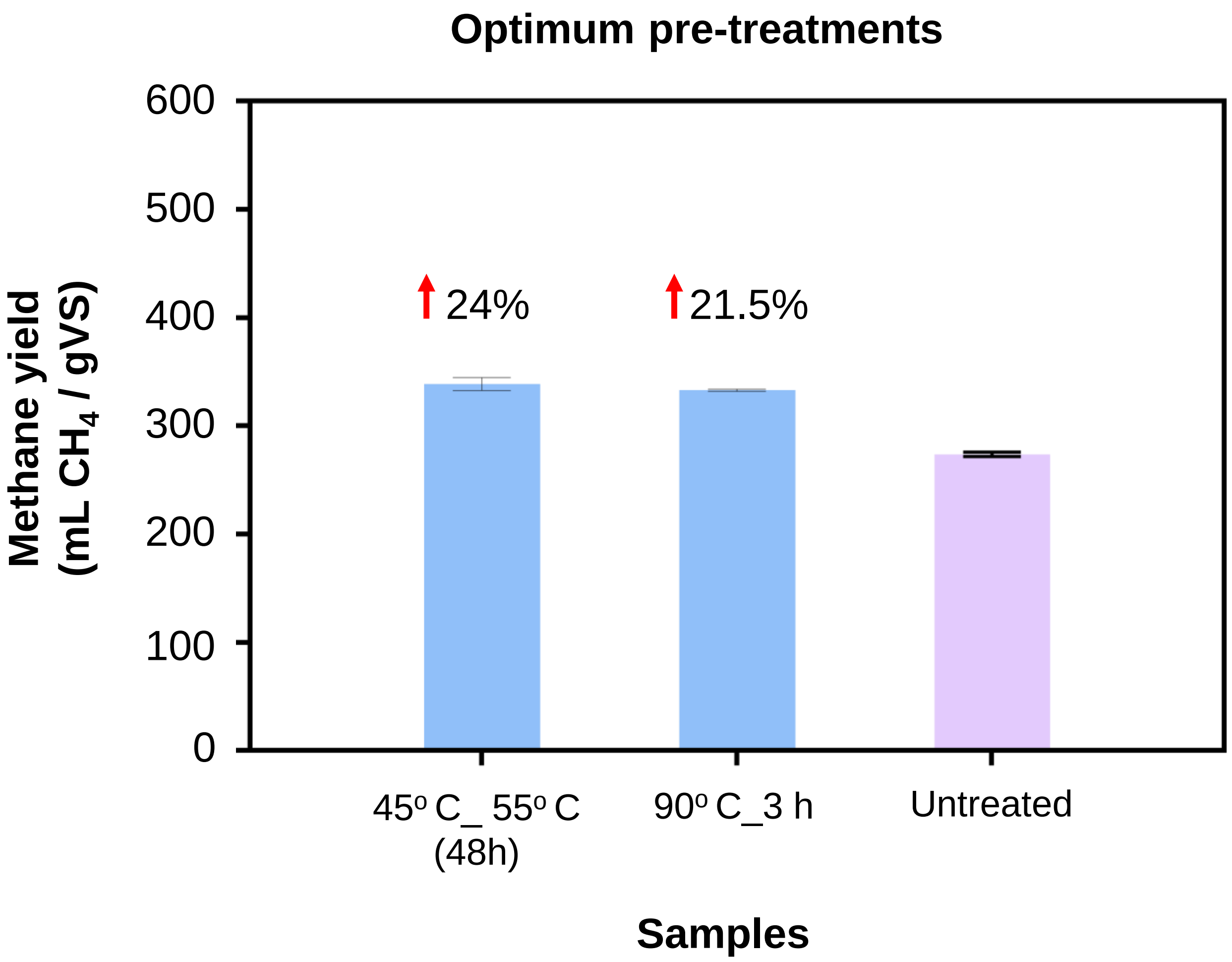
✓ **Enhanced Anaerobic Digestion efficiency**
  ✓ **Increased Biogas Production**



Evaluation of different pre-treatments

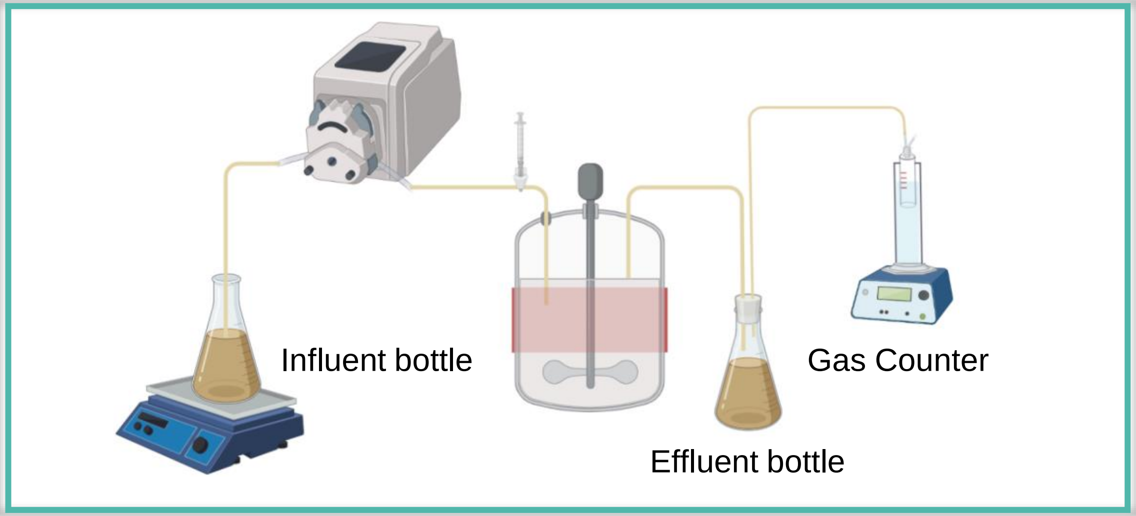
Thermal Hydrolysis	
1	45º C for 48 h and then 55º C for extra 48 h
2	45º C for 72 h and then 55º C for extra 72 h
3	45º C for 72 h and then 55º C for extra 72 h under 0.5 bar of CO_2 pressure
4	45º C for 72 h and then 55º C for extra 72 h under 1.0 bar of CO_2 pressure
5	90º C for 3 h
6	90º C for 3 h under 0.5 bar of CO_2 pressure
7	90º C for 3 h under 1 bar of CO_2 pressure
Alkaline Hydrolysis	
8	2% v/v NaOH
9	4% v/v NaOH
Thermochemical pre-treatments	
10	4% v/v NaOH, 45º C for 72 h and then 55º C for extra 72 h
11	4% v/v NaOH, 45º C for 72 h and then 55º C for extra 72 h, under 0.5 bar of CO_2 pressure
12	4% v/v NaOH, 45º C for 72 h and then 55º C for extra 72 h, under 1 bar of CO_2 pressure
13	4% v/v NaOH and 90º C for 3 h, under 0.5 bar of CO_2 pressure
14	4% v/v NaOH and 90º C for 3 h, under 1 bar of CO_2 pressure

Aim & Objectives



Further evaluation
through continuous reactor operation

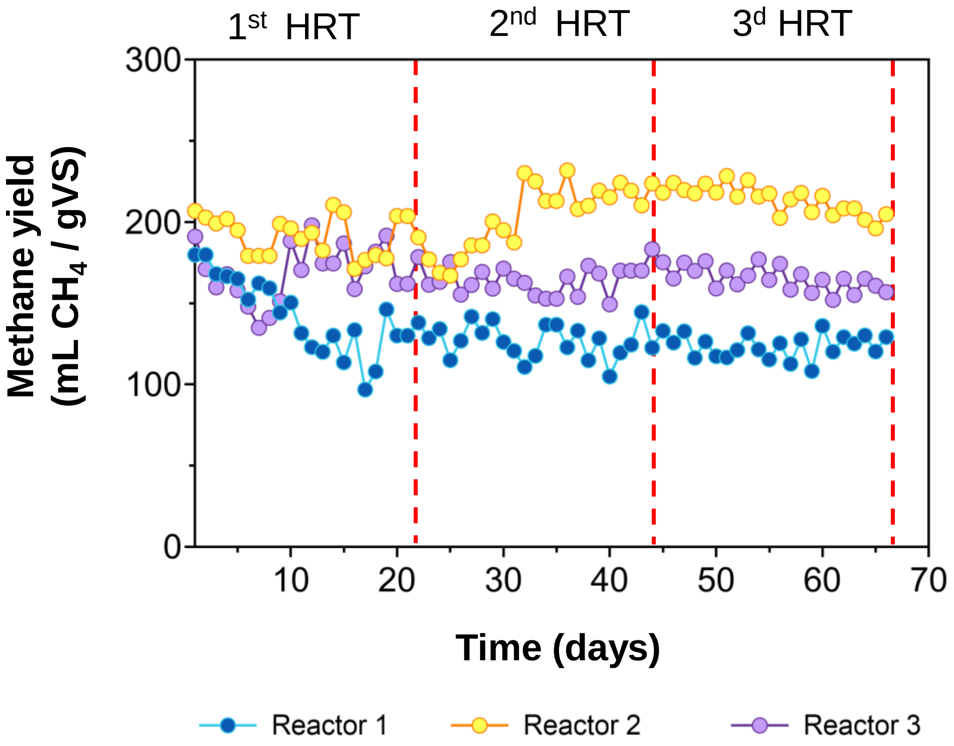
Experimental set-up

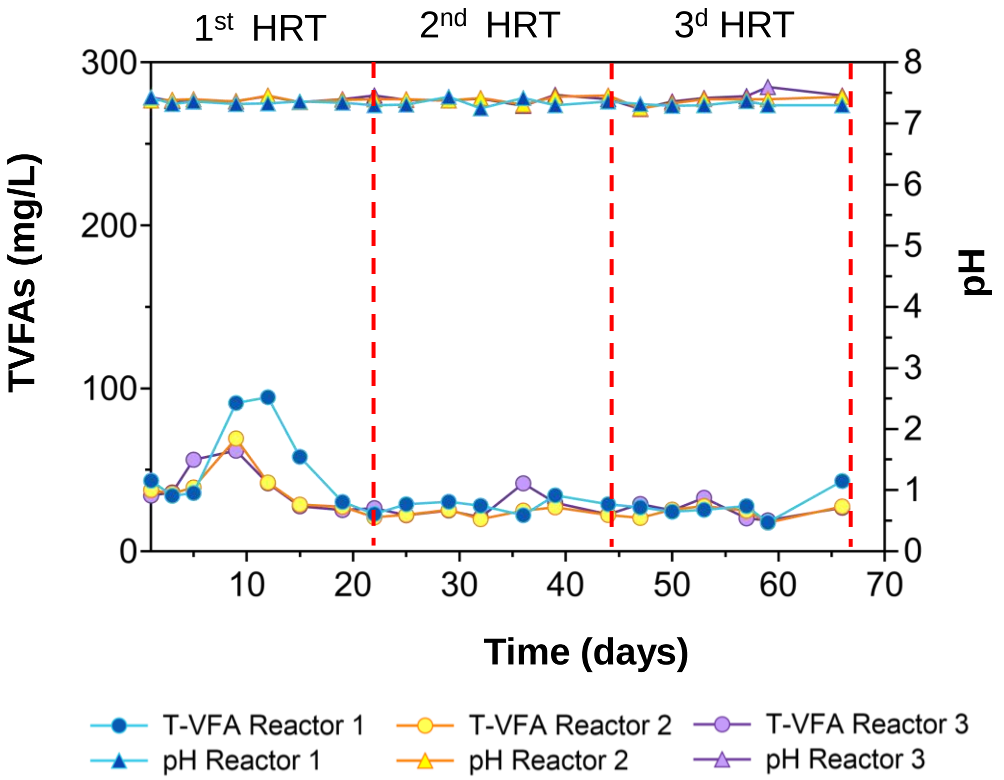


- 3 CSTRs
  Reactor 1: **Un**-treated sludge
  Reactor 2: **Pre**-treated sludge (45^{o}C for 48 h & 55^{o}C for 48 h)
  Reactor 3: **Pre**-treated sludge (90^{o}C for 3 h)
- Mesophilic Conditions (37 ± 2^{o} C)
- 3 periods → Increasing Organic Loading Rate (OLR)
- Biochemical parameters x2/week
- DNA extraction (Period 1 and Period 2) → Effect of sludge thickening on microbial community

1st Experimental Period

- Hydraulic Retention Time: HRT = 22 days
- OLR = 1 (g VS/(LReactor*day))

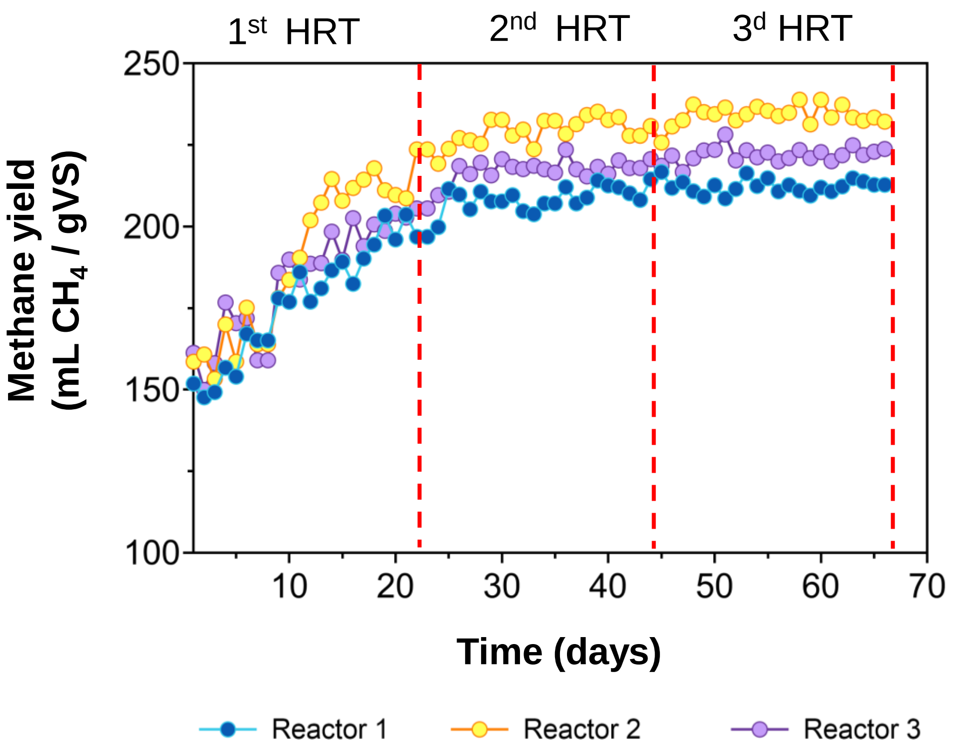


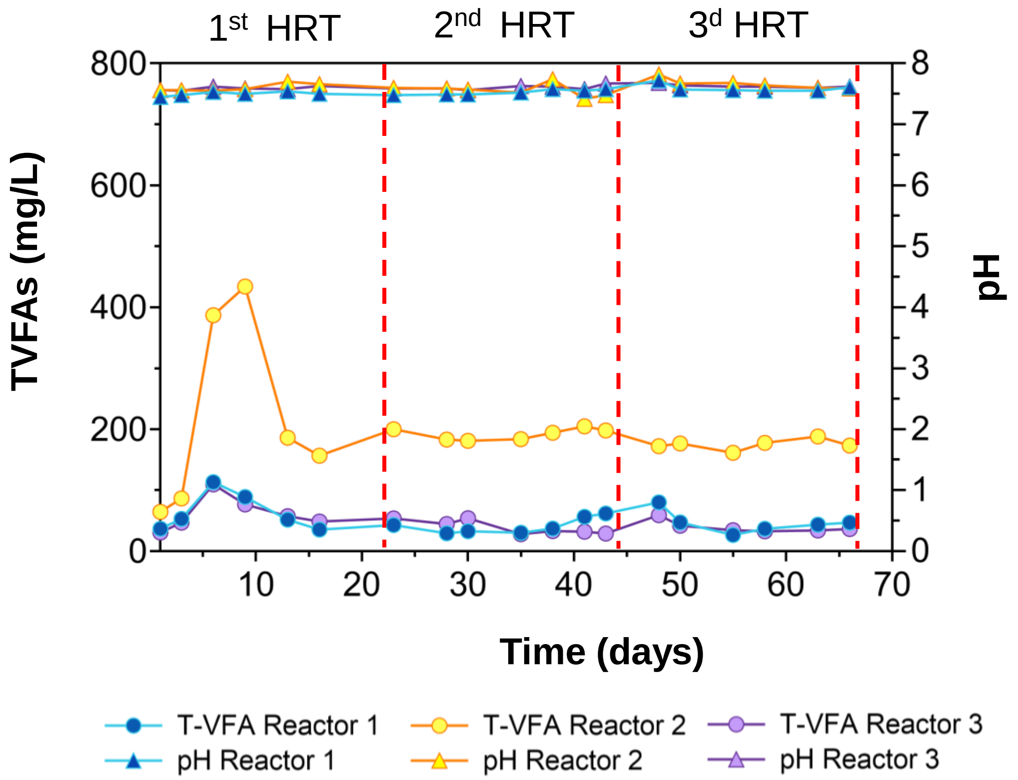


126 ± 9.69 mL CH_4/g VS	**207 ± 6.78 mL CH_4/g VS**	**161 ± 7.47 mL CH_4/g VS**

2^{nd} Experimental Period

- Feeding: **Thickened** Sludge
- Hydraulic Retention Time: HRT = 22 days
- OLR = 2 (g VS/($L_{Reactor}$*day))





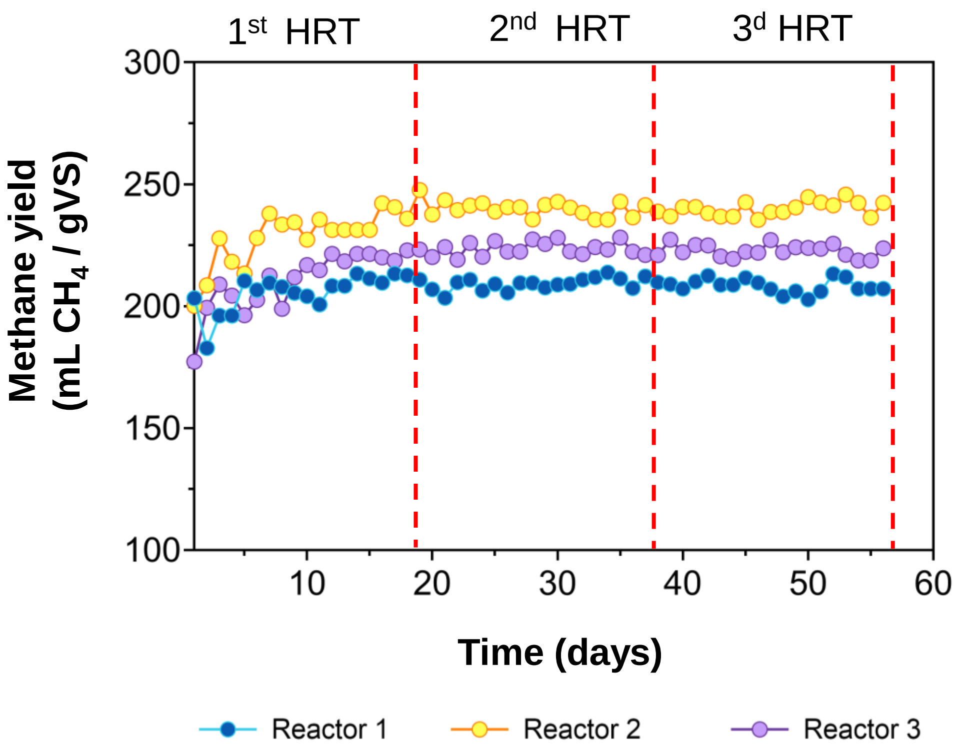
212 ± 1.47 mL CH_4/g VS

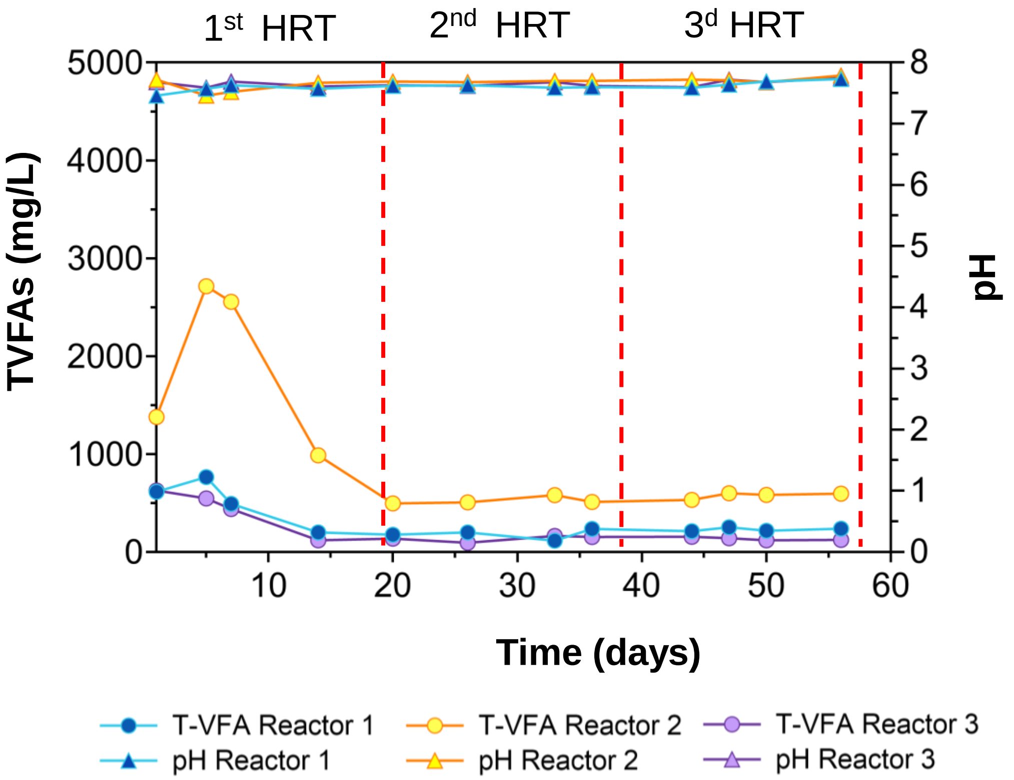
234 ± 2.52 mL CH_4/g VS

222 ± 1.52 mL CH_4/g VS

3rd Experimental Period

- Feeding: **Thickened** Sludge
- Hydraulic Retention Time: HRT = 18 days
- OLR = 2.5 (g VS/($L_{Reactor}$*day))





207 ± 2.96 mL CH_4/g VS

240 ± 3.09 mL CH_4/g VS

224 ± 2.49 mL CH_4/g VS

Microbial composition changes

Most abundant

Synergistota:

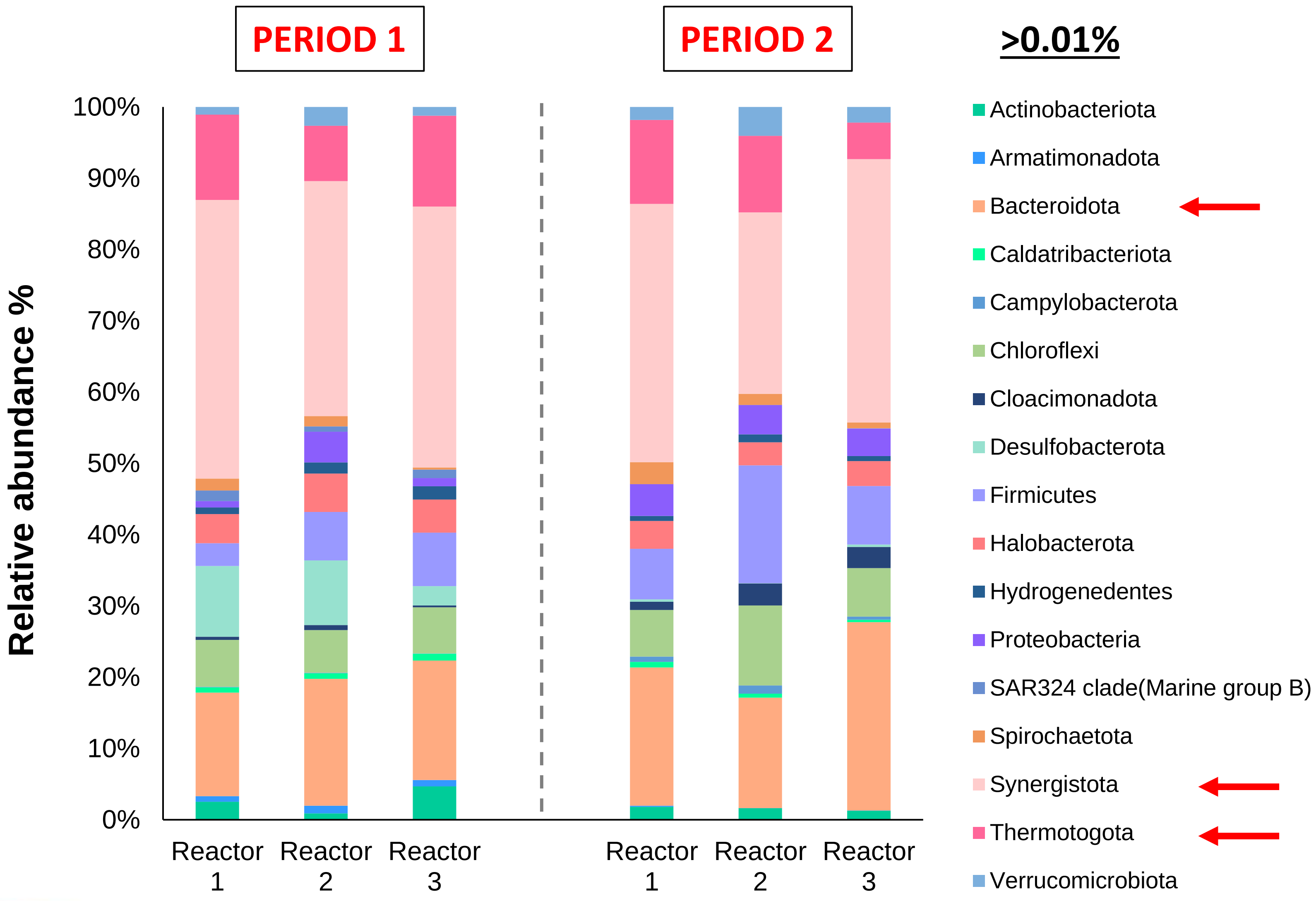
- ***Thermovirga*** sp.: can degrade amino acids, but also reported to participate in the direct interspecies electron transfer (DIET) of microorganisms.

Thermotogota:

- ***Mesotoga*** sp.: linked to the syntrophic acetate oxidation.

Bacteroidota:

- ***DMER64*** sp.: anaerobic mesophilic acetogens usually present in various of digester systems and reported to involve in interspecies hydrogen transfer (IHT) as main H_2 carriers.



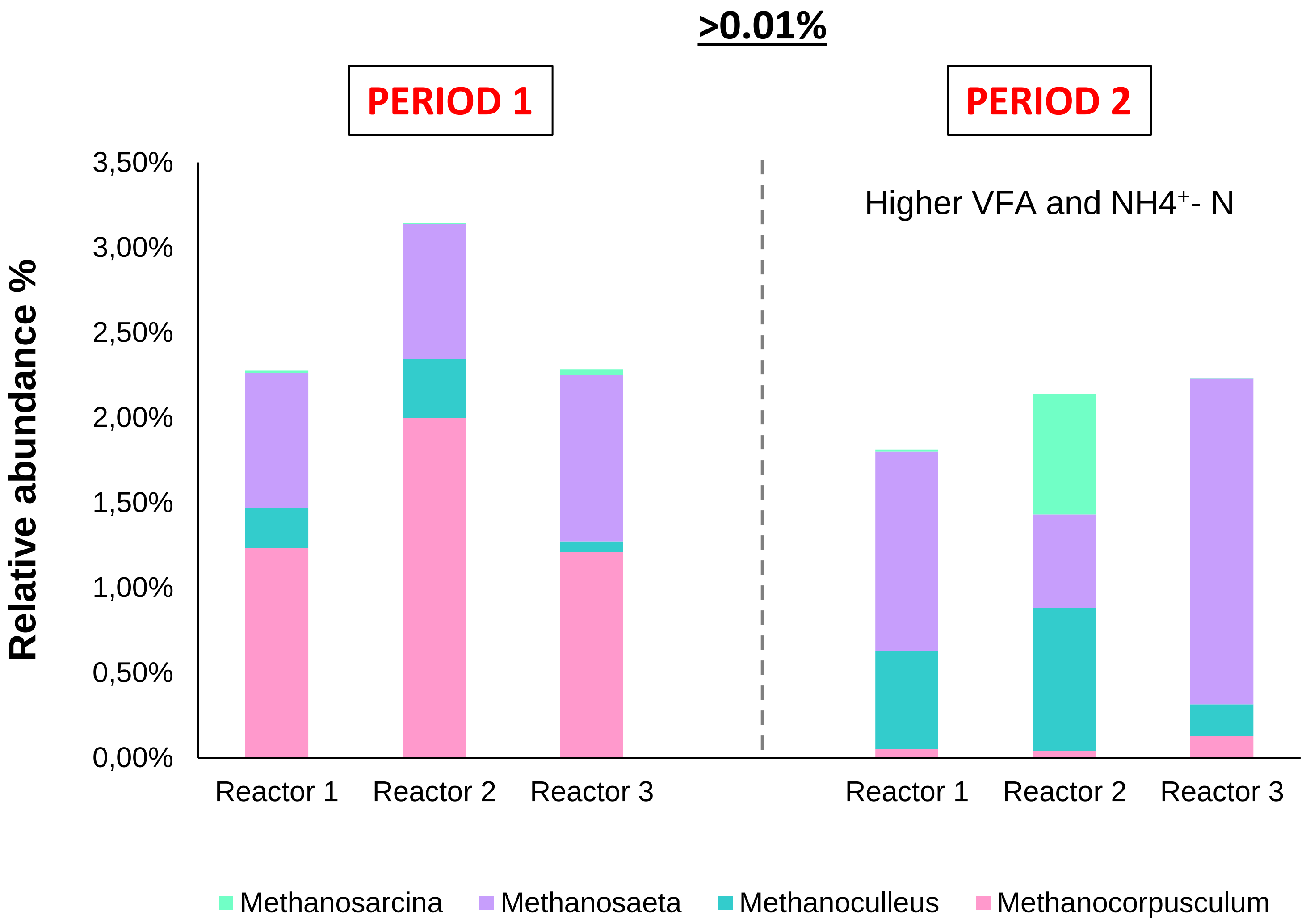
Methanogenic composition changes

- ***Methanocorpuscullum*** sp.: hydrogenotrophic methanogens that can be negatively affected by acetate, propionate and total ammonium nitrogen (TAN).

- ***Methanoculleus*** sp.: Hydrogenotrophic methanogens with positive correlation to TAN.

- ***Methanosarcina*** sp.: metabolically versatile microorganisms and vulnerable to process inhibitors such as free ammonia and VFAs.

- ***Methanosaeta*** sp: core genus involved in aceticlastic pathway.



Foaming Bacteria

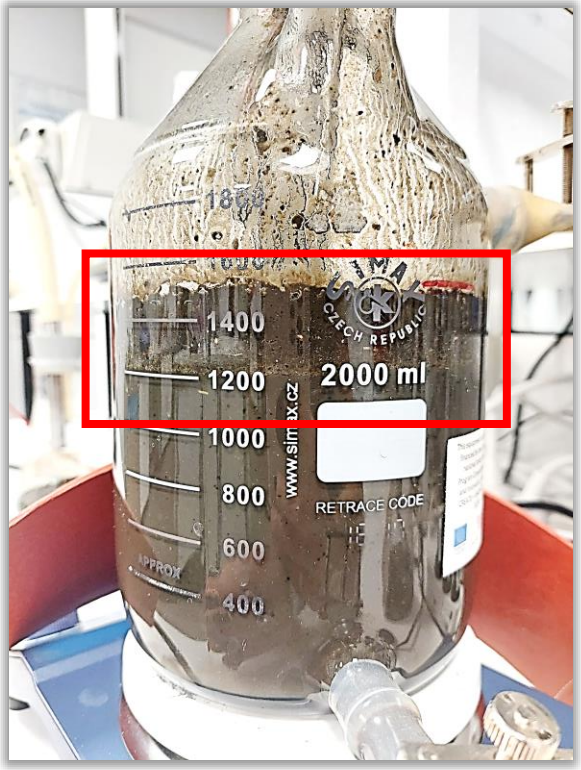
PERIOD 2

1. Foam sampling from **each** effluent bottle
2. DNA extraction & 16S rRNA amplicon sequencing

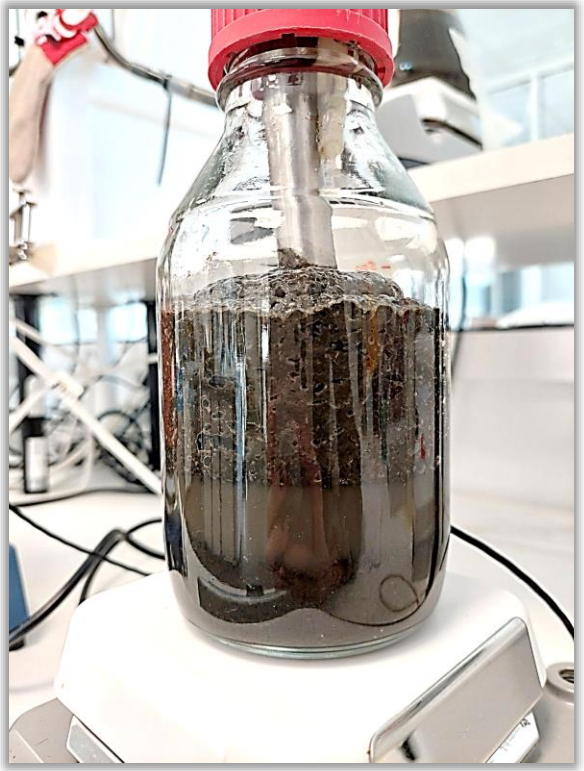
> 0.5% abundance in all the samples

***Corynebacteriales* order**:

- *Corynebacterium* sp.
- *Mycobacterium* sp.
- *Gordonia* sp.



Reactor



Effluent bottle

Conclusions

- ✓ The reactor fed with sludge pretreated at **45º C for 48h and then at 55ºC for additional 48h** led to the **highest performance** in terms of methane yield, during all the experimental periods examined.

- ✓ A further increase in organic loading rate up to 2.5 gVS $L_{Reactor}^{-1}d^{-1}$ **did not** lead to higher efficiencies in terms of methane yield.

- ✓ Sludge **thickening altered** the bacterial and archaeal communities of the reactors during the second experimental period, as a response to the incremental change in TS content and unfavorable environment (i.e. VFA stress).

- ✓ **Foam forming filamentous bacteria** were detected in all the samples obtained from effluent bottles during period 2 and OLR equal to 2 gVS $L_{Reactor}^{-1}d^{-1}$.

Future experimental work

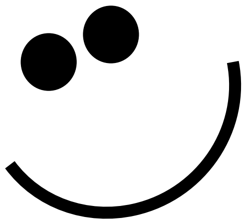
SWRI
Soil and Water Resources Institute
Waste-Management-Bioprocessing-Lab

- ✓ Total volume approx. 800 L
- ✓ Working volume approx. 600 L
- ✓ Mesophilic conditions
- ✓ Two-stage thermal pre-treatment

Acknowledgement

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T2EDK-01293, BiogasUp).

Thank you for your attention!



SWRI Soil and Water Resources Institute

CHANIA2023 21-24 JUNE chania2023.uest.gr

WMB Waste·Management·Bioprocessing·Lab

10th International Conference on Sustainable Solid Waste Management
Chania, Greece, 20 - 25 JUNE 2023

Evaluation of the optimal sewage sludge pre-treatment technology through continuous reactor operation

G.-C. Mitraka[1,2], K.N. Kontogiannopoulos[1], A.I Zouboulis[2], P.G. Kougias[1]

[1]Soil and Water Resources Institute, Hellenic Agricultural Organization – Dimitra, Thermi, Greece
[2]Laboratory of Chemical & Environmental Technology, Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

@WMBlab @wmb_lab Thermi-Thessaloniki, GR