Biological removal of siloxanes from biogas for biomethane injection in natural gas grid

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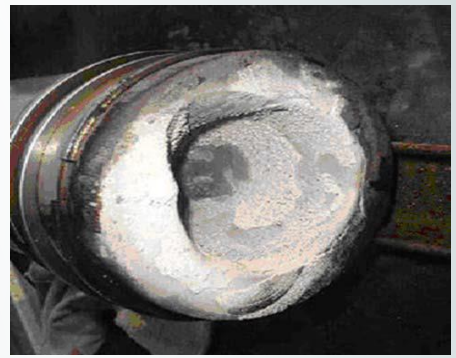
INTRODUCTION

- Biogas contains trace level concentrations of volatile methyl siloxanes (VMS)

SiO_2 ⟶ crystalline deposit

  - Decreased efficiency of the equipment
    - Corrosion
    - Erosion
    - Clogging of pipes
  - Increased maintenance costs



- Removal of VMS from biogas prior energy valorization is mandatory

Siloxanes concentration in biogas = 20-400 mg m^{-3}

⬇

Maximum concentration for biomethane injection in natural gas grid

10 mg m^{-3}

INTRODUCTION

➢ Conventional physical-chemical processes for siloxanes removal:

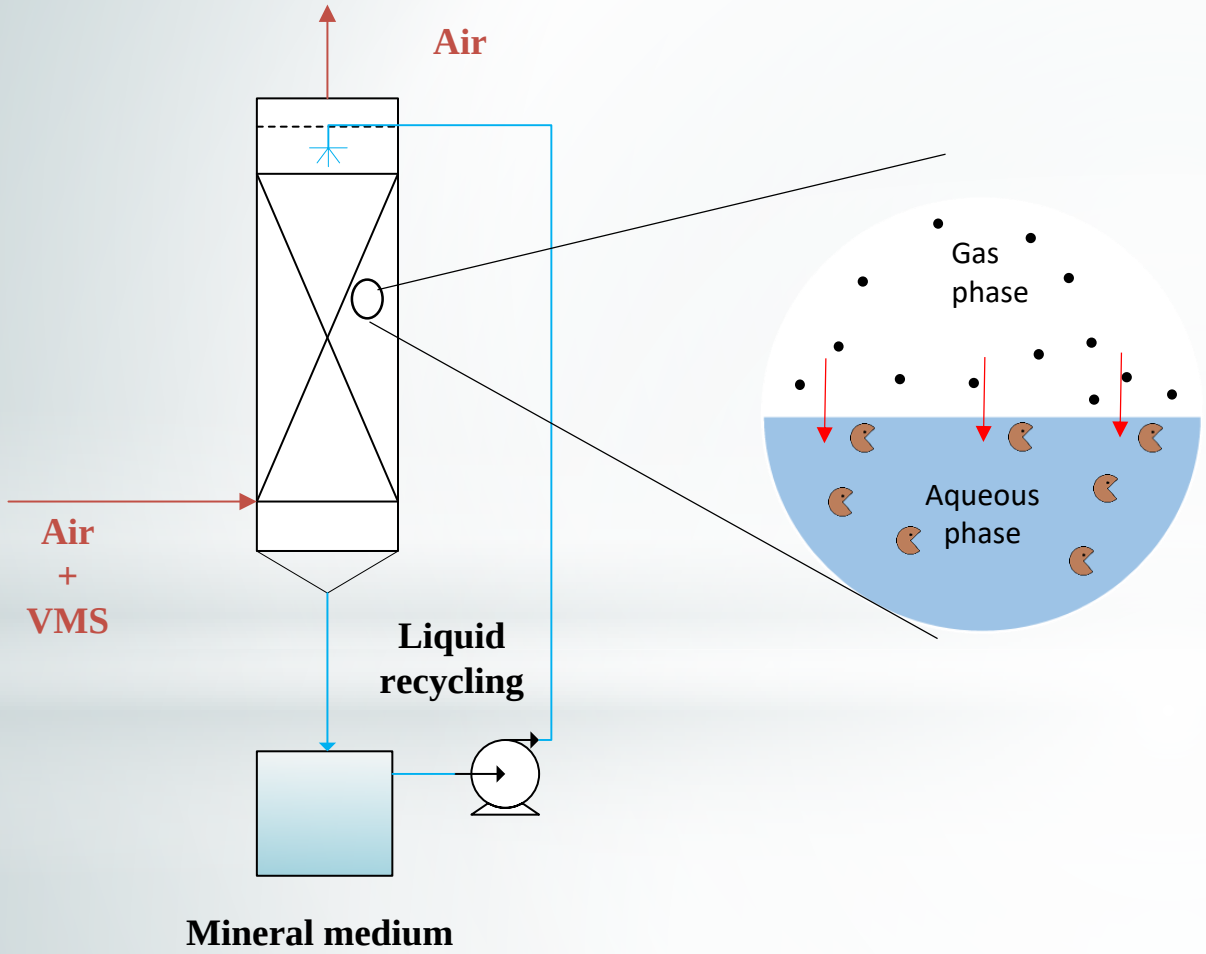
- High operating and investment cost

Physical-chemical processes	RE (%)	Disadvantages
Adsorption	90-99	Regeneration/replacement of the adsorbent
Absorption	> 90	Cooling to avoid organic solvent emissions Corrosive nature of acid solutions Alkaline deposits (alkaline absorbent solutions)
Cryogenic condensation	> 90	Extreme operating temperatures (-25, -70 ºC)
Membrane separation	> 80	Compressors or vacuum pumps energy consumption

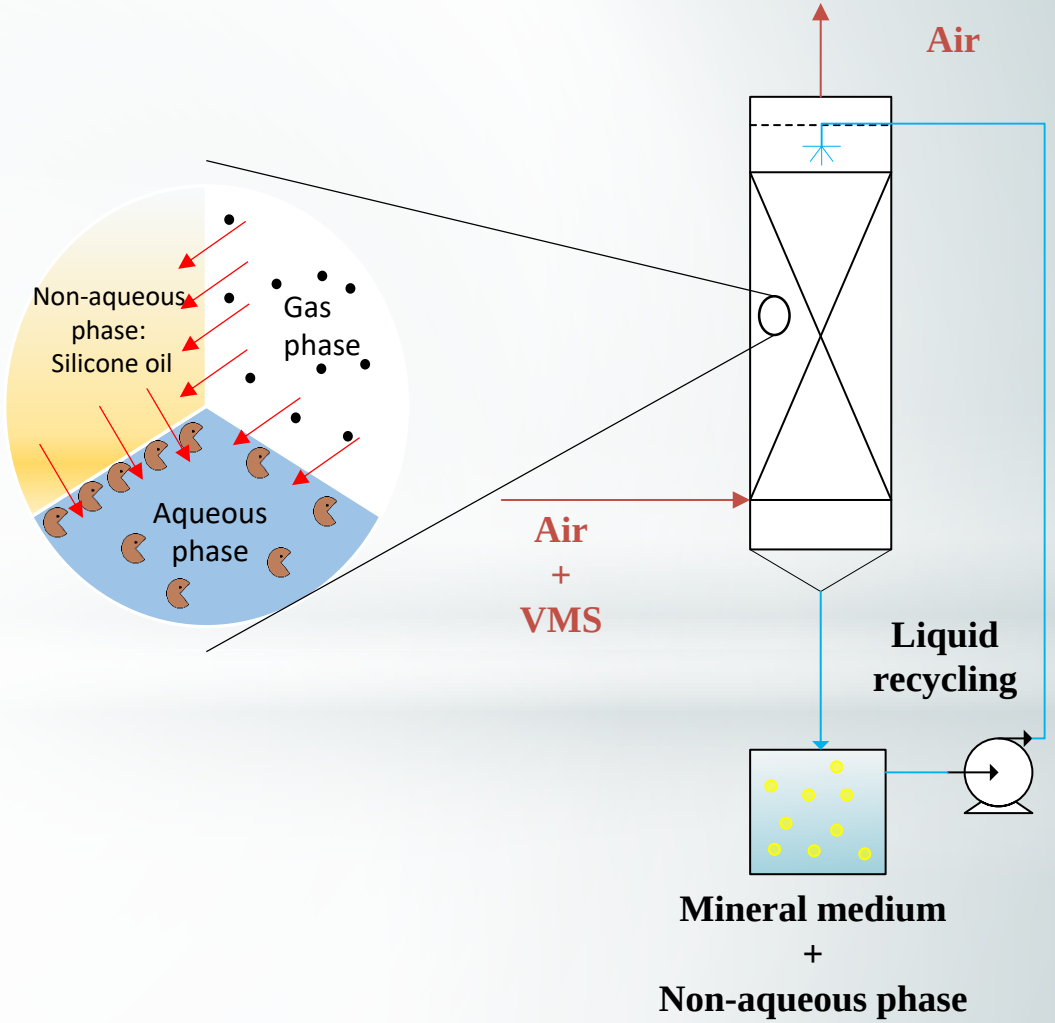
➢Biological processes:

- Low-cost
- Environmentally friendly

Biotrickling Filters (BTFs)



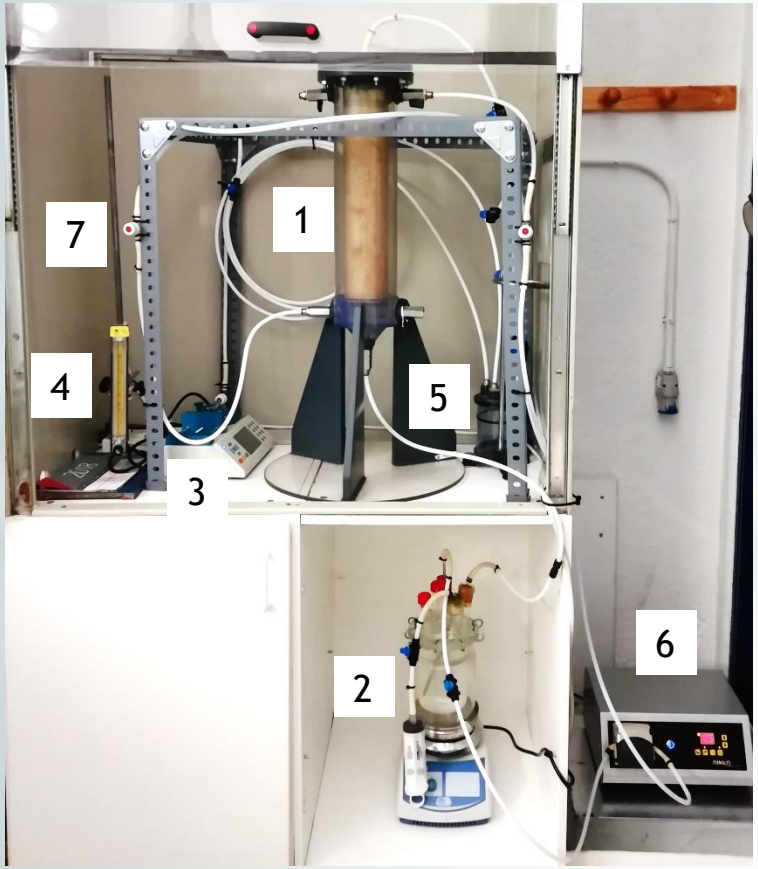
One-phase biotrickling filter (1P-BTF)

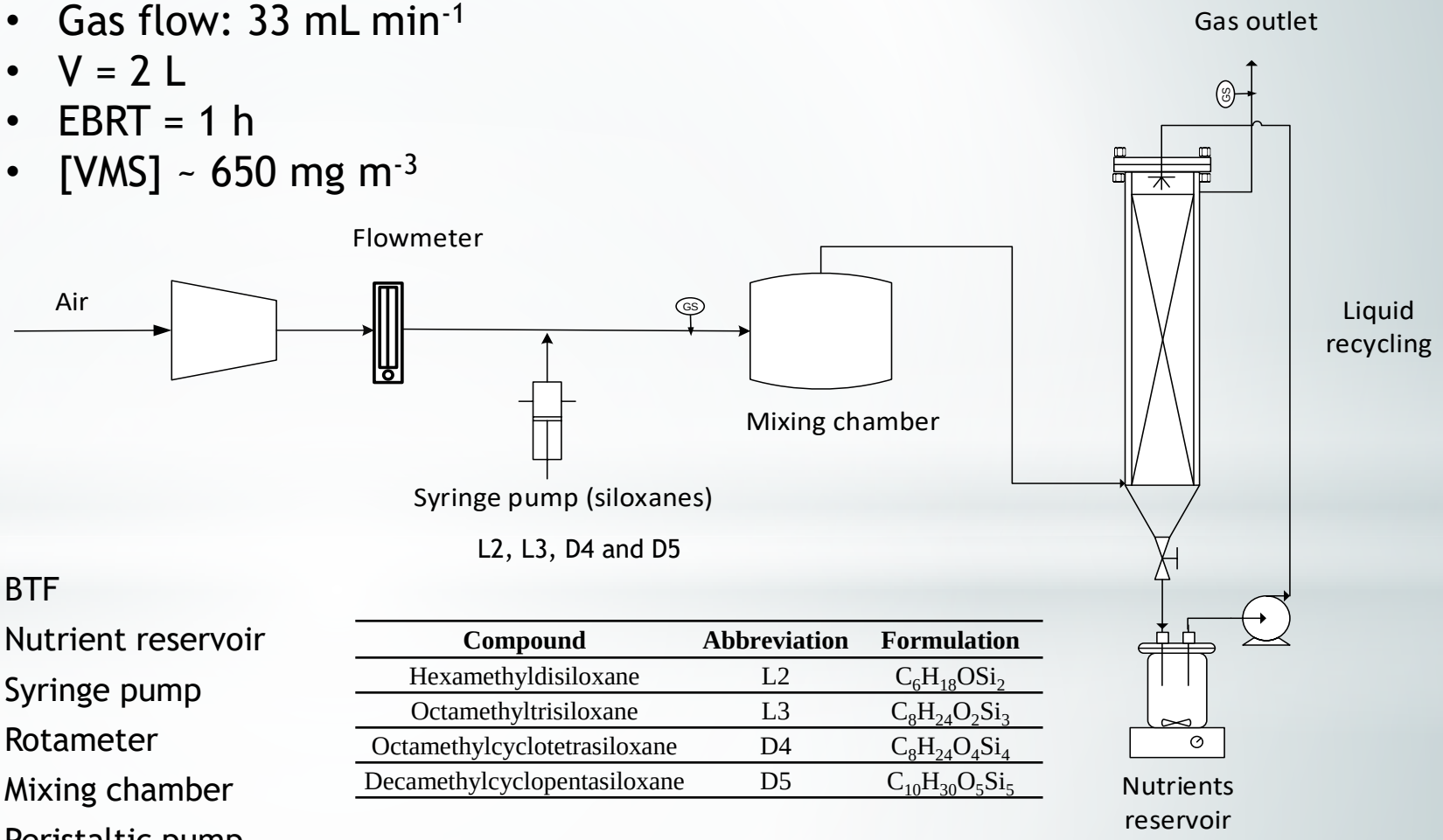


Two-phase partitioning biotrickling filter (TP-BTF)

BTFs: Experimental setup

- Gas flow: 33 mL min^{-1}
- V = 2 L
- EBRT = 1 h
- [VMS] ~ 650 mg m^{-3}

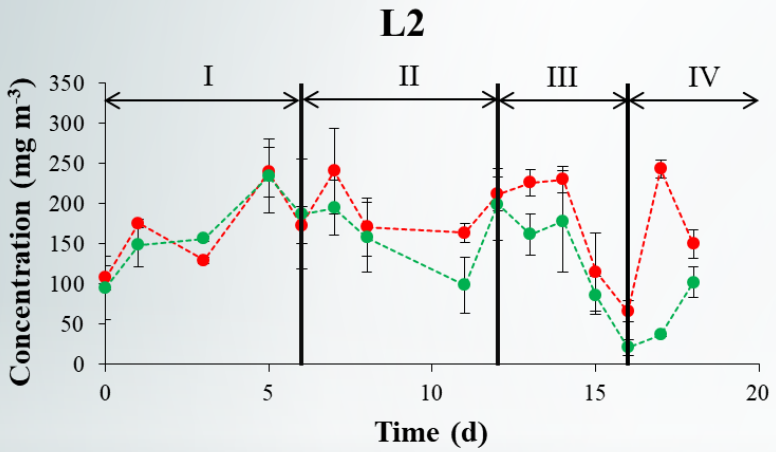


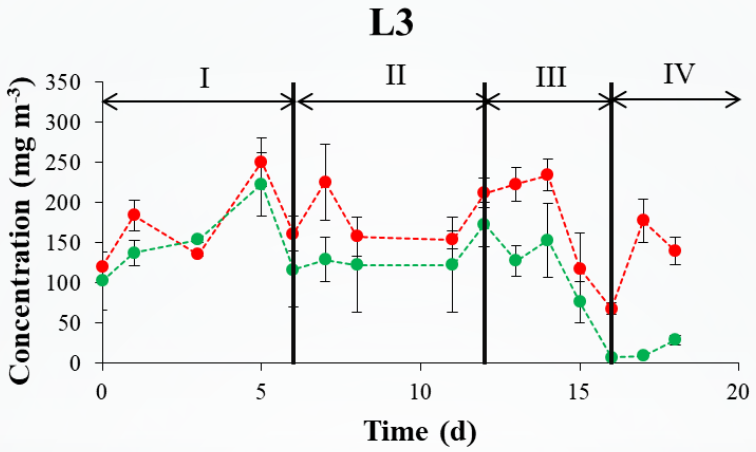


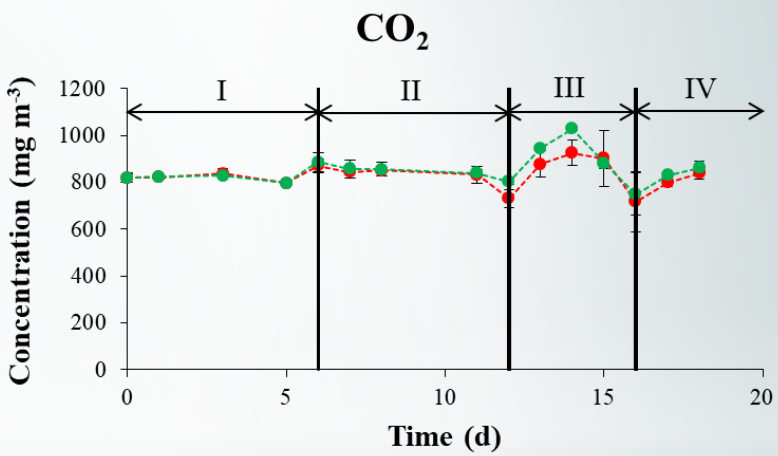
1- BTF
2- Nutrient reservoir
3- Syringe pump
4- Rotameter
5- Mixing chamber
6- Peristaltic pump
7- Gas sampling port

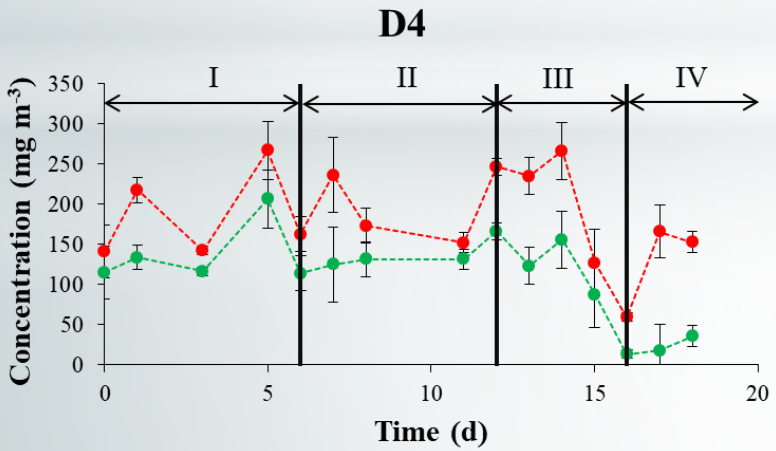
Compound	Abbreviation	Formulation
Hexamethyldisiloxane	L2	$C_6H_{18}OSi_2$
Octamethyltrisiloxane	L3	$C_8H_{24}O_2Si_3$
Octamethylcyclotetrasiloxane	D4	$C_8H_{24}O_4Si_4$
Decamethylcyclopentasiloxane	D5	$C_{10}H_{30}O_5Si_5$

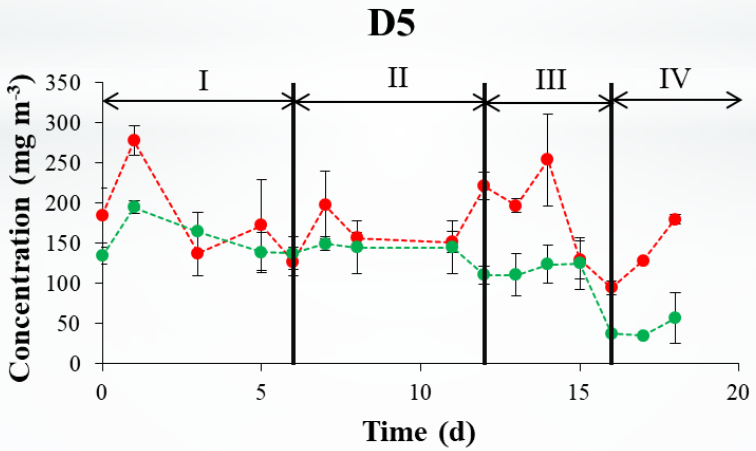
BTFs: Abiotic test











Inlet concentration (●)
Outlet concentration (●)

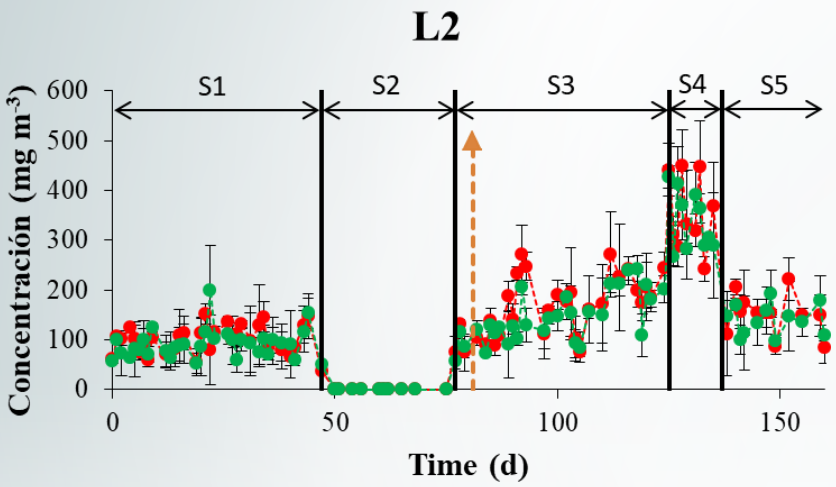
PVC column (I)
Packing material (II)
Mineral medium (III)
Mineral medium + silicone oil (IV)

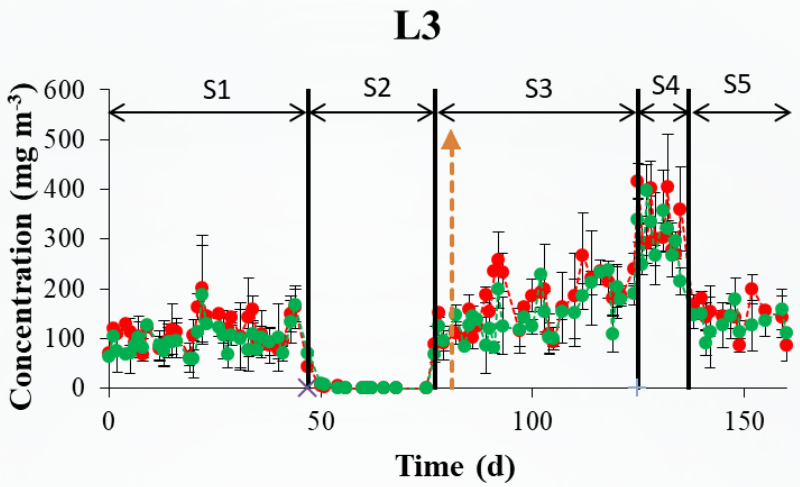
BTFs: Experimental conditions

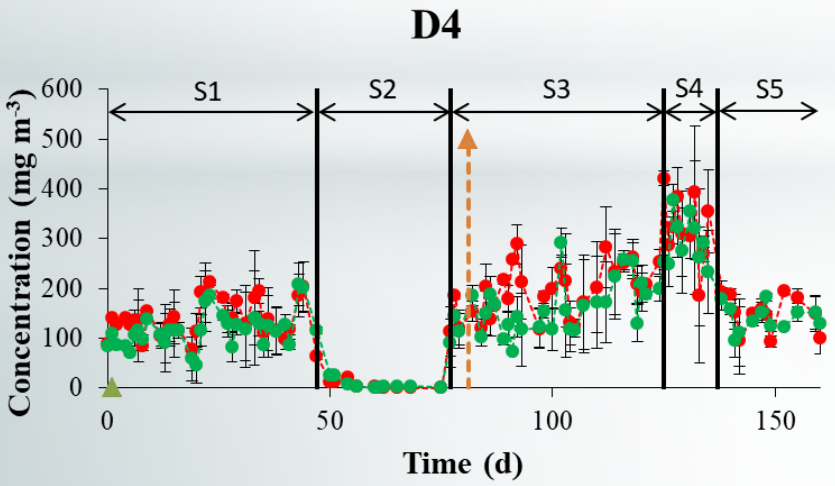
1P-BTF	Feed Stream	Time curse (Days)	VMS Concentration (mg m^{-3})
S1	VMS loaded air stream	0 - 46	514.7 ± 125.6
S2	Clean air stream	47 - 76	-
S3	VMS loaded air stream	77 - 124	719.3 ± 203.4
S4	VMS loaded air stream	125 -137	1287.9 ± 216.8
S5	VMS loaded air stream	138 - 160	650.9 ± 126.9

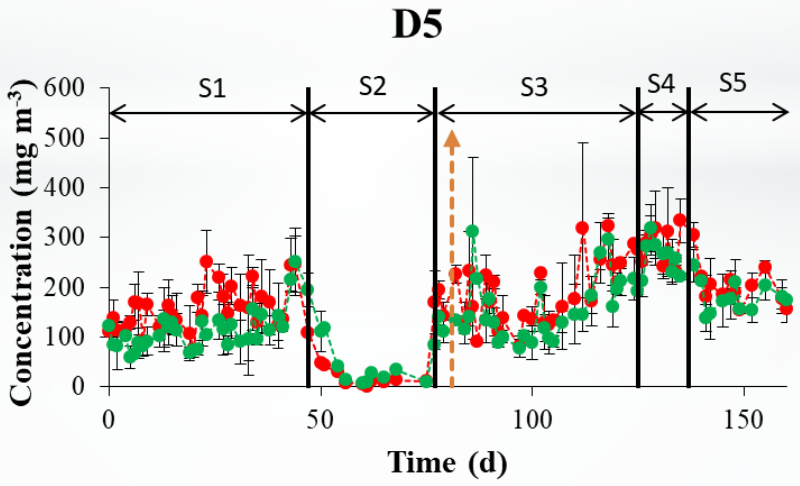
TP-BTF	Feed Stream	Time curse (Days)	VMS Concentration (mg m^{-3})
S1	VMS loaded air stream	0 - 21	624.0 ± 172.4
S2	Clean air stream	22 - 70	-
S3	VMS loaded air stream	70 - 113	640.0 ± 198.0

1P-BTF: VMS concentration and RE

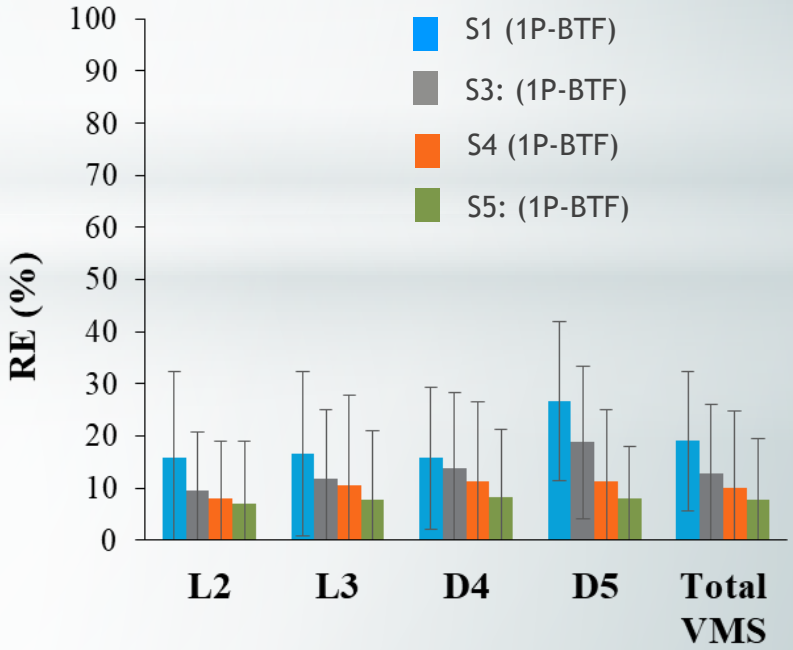






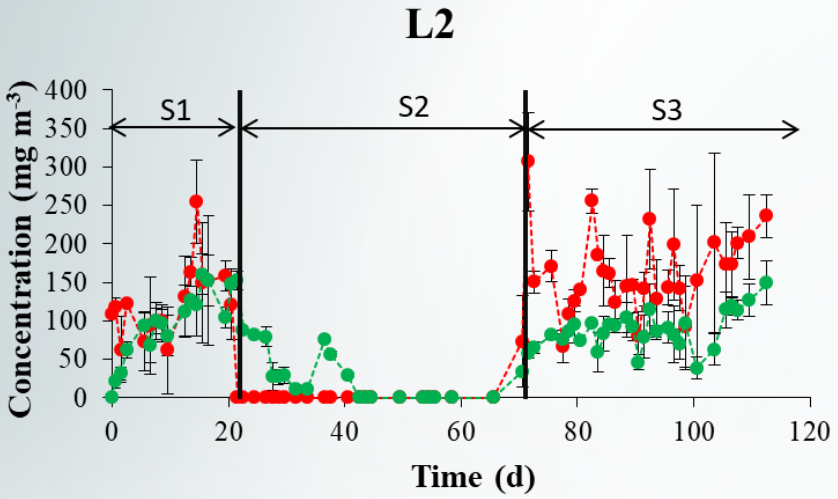


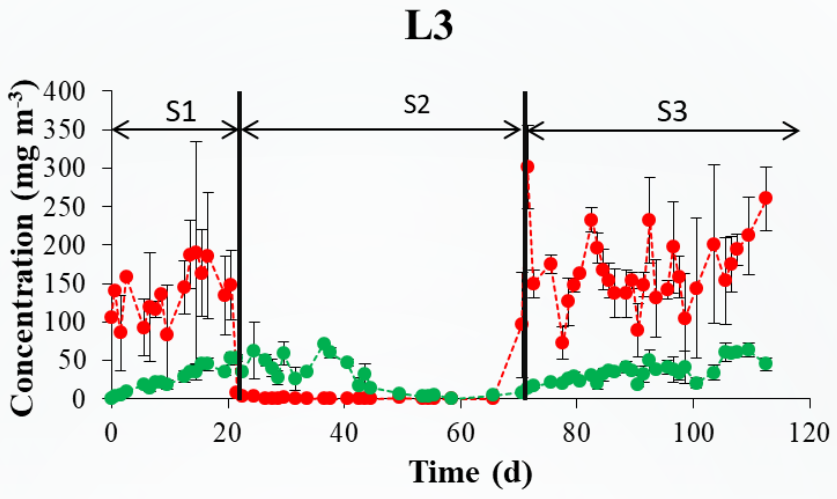
	VMS Concentration (mg m^{-3})
S1	514.7
S2	-
S3	719.3
S4	1287.9
S5	650.9



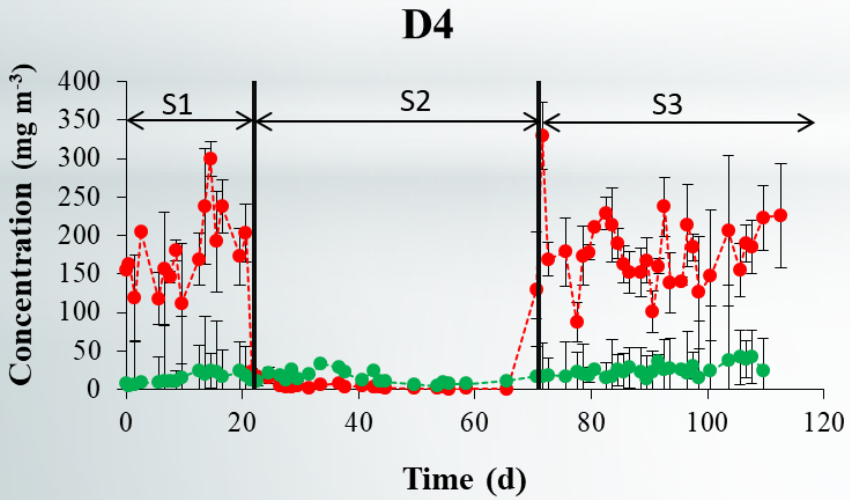
Inlet concentration (●)
Outlet concentration (●)
Day 81: System reinoculation (----→)

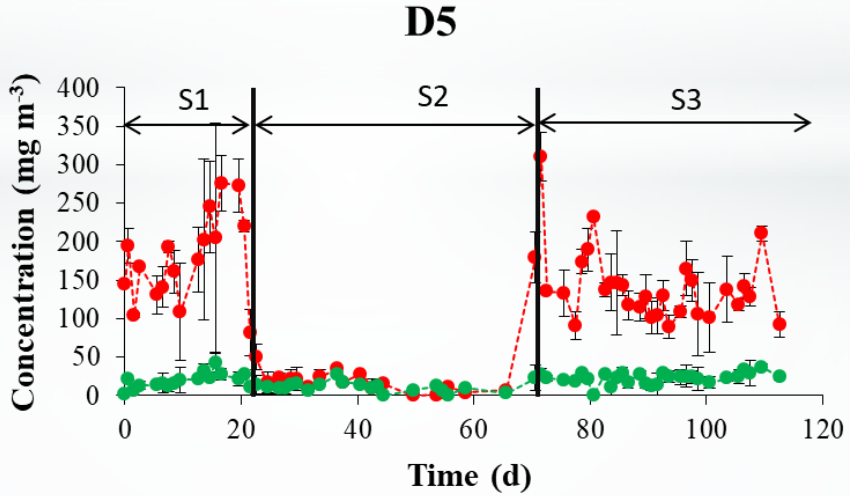
TP-BTF: VMS concentration and RE

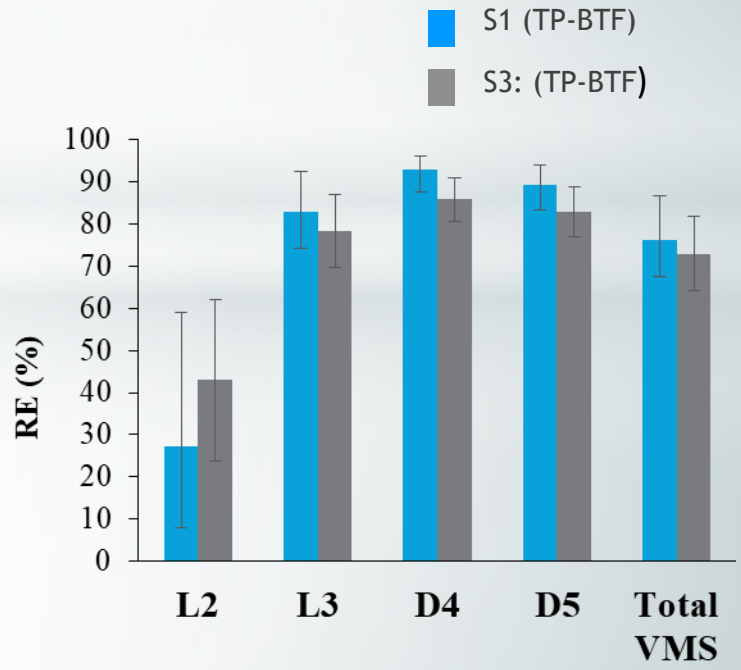




	VMS Concentration (mg m^{-3})
S1	624.0
S2	-
S3	640.0

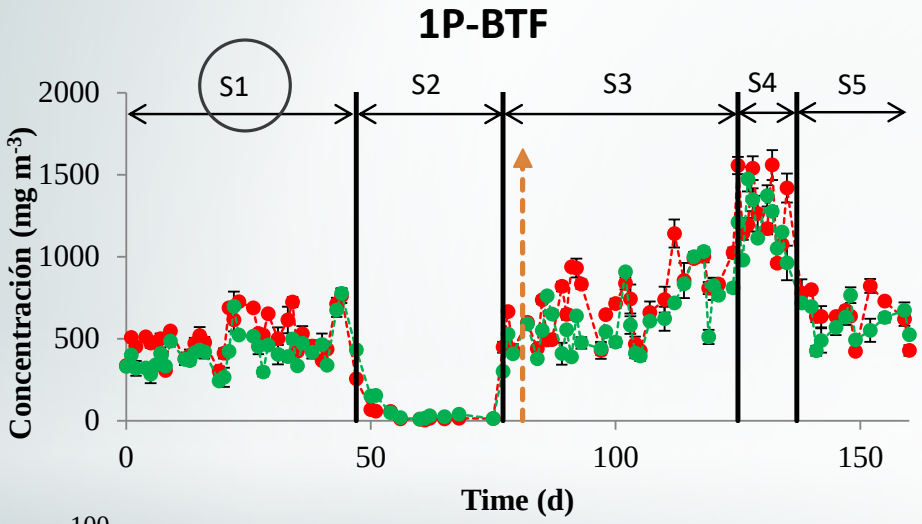


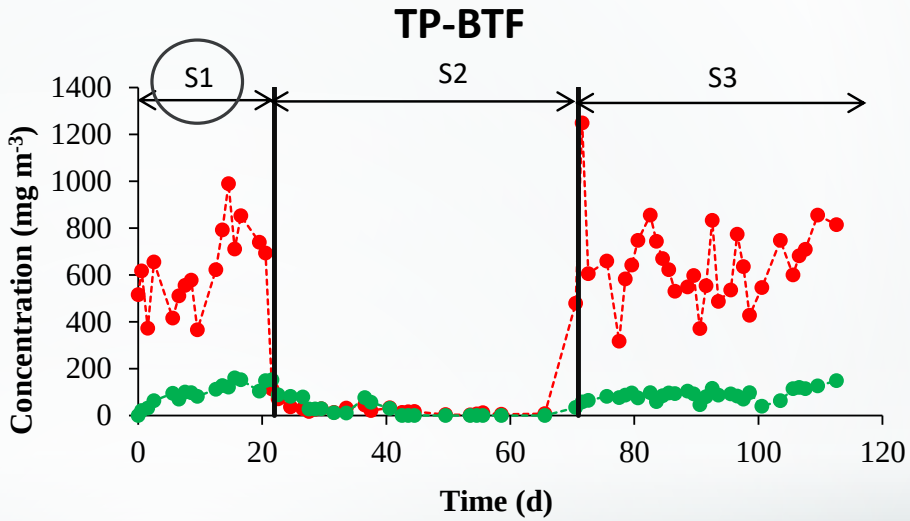




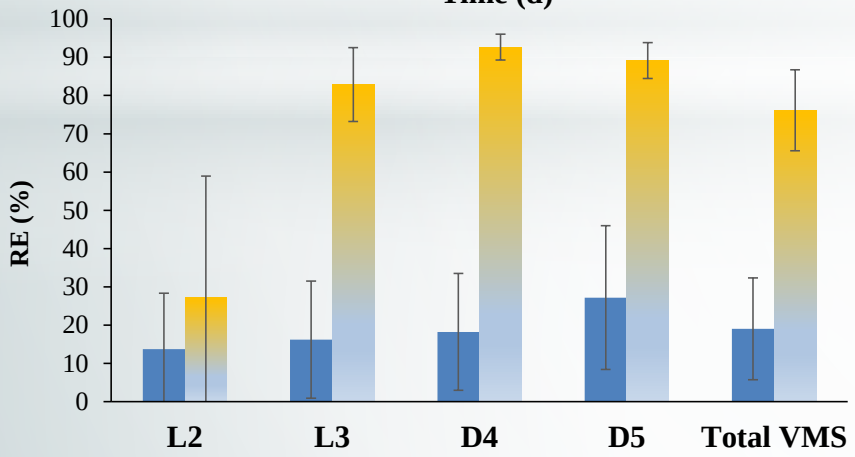
Inlet concentration (●)
Outlet concentration (●)

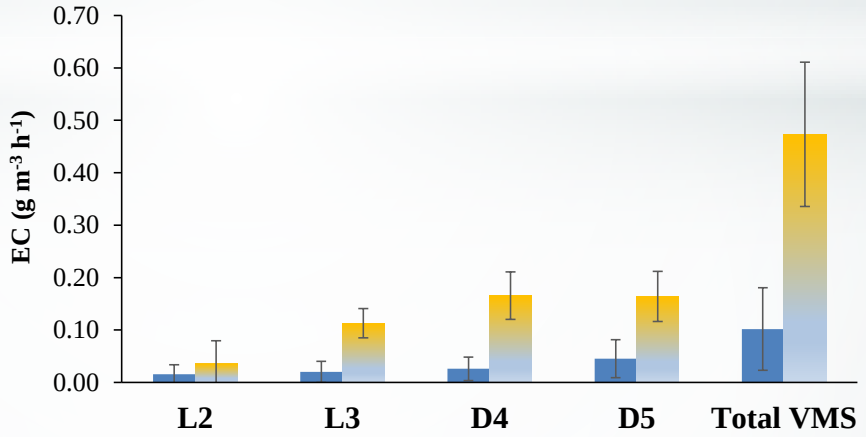
Total VMS removal - Comparative results





Inlet total VMS concentration (●)
Outlet total VMS concentration (●)
Day 81: System reinoculation (- - - →)





1P-BTF (S1)
TP-BTF (S1)

Conclusions

- REs and ECs significantly higher in TP-BTF compared to 1P-BTF (~ 80 % higher)
  - VMS low solubility in aqueous phase
  - Reduced mass transfer
- The presence of an organic phase (silicon oil) is of key importance in VMS removal
- The highest REs were obtained for D4 and D5 (the compounds with highest molecular weight and lowest volatility)
- Future work:
  - Study of the microbial communities in siloxane removal TP-BTF
  - Metabolites analysis
  - Optimization of lab-scale BTF for siloxanes removal
    - Lower EBRT
    - VMS removal under anoxic conditions

Thanks for your attention

Biological removal of siloxanes from biogas for biomethane injection in natural gas grid

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