Biotrickling filtration as sustainable technology for biogas upgrading to renewable fuel

Eric Santos-Clotas*, Alba Cabrera-Codony, Eliana Boada, Frederic Gich, Maria J. Martin
*eric.santos@udg.edu

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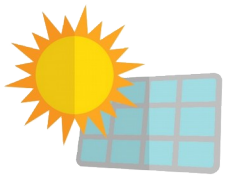
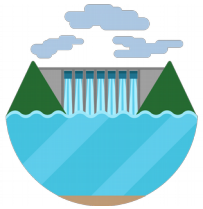
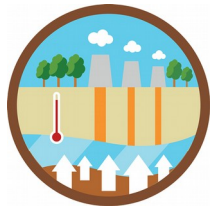
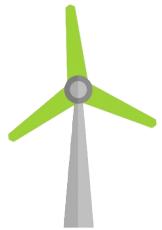





- Chemical stability
- Hydrophobicity
- Low surface tension
- Aroma free
- Exempts from VOC regulations

→ SILOXANES **[10 - 100 mg m^{-3}]**

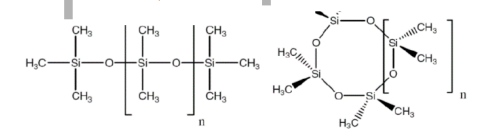
→ Volatile organic compounds

→ **Hydrogen sulphide** **[1,000 – 20,000 ppm$_v$]**

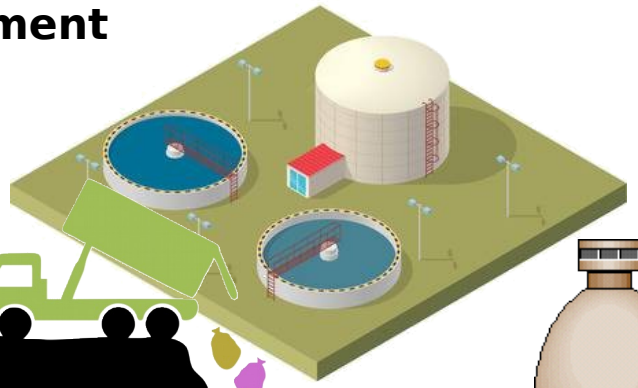
VOLATILE METHYL SILOXANES

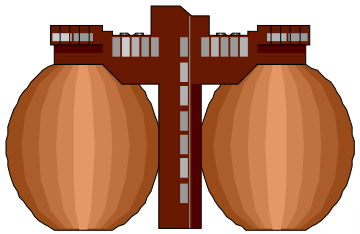
LINEAR L_{Si}

CYCLIC D_{Si}



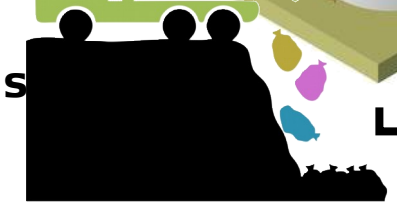
Wastewater treatment plant

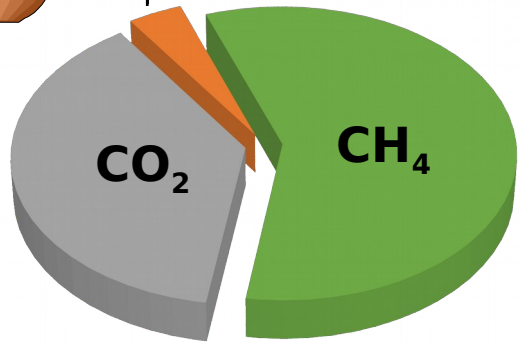




Anaerobic digestion

Landfills





BIOGAS

Energetic valorisation of biogas

Heat and electricity
Gas grid injection
Car fuel

Combustion reactions: Siloxanes → SiO_2

Build-up of silica layers
Abrasion of engine parts
Inhibits conduction/lubrication

BIOGAS

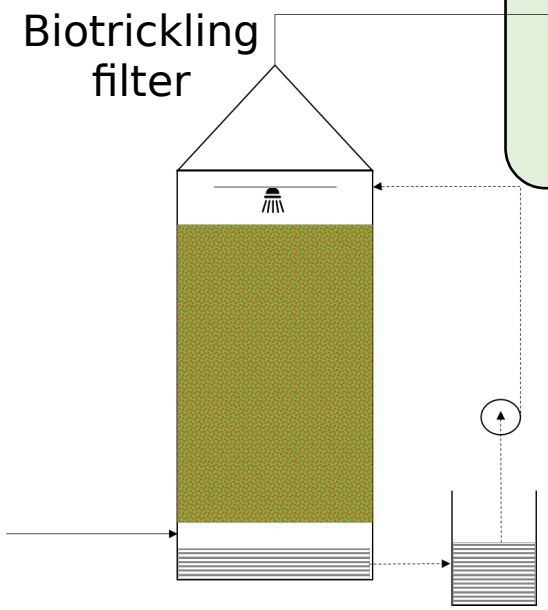
H_2S H_2O Siloxanes

Adsorption [Steam-AC]

Energy recovery system

Alternative technologies

Biotrickling filter



Reduce investment and operation costs

Increment treatment capacities

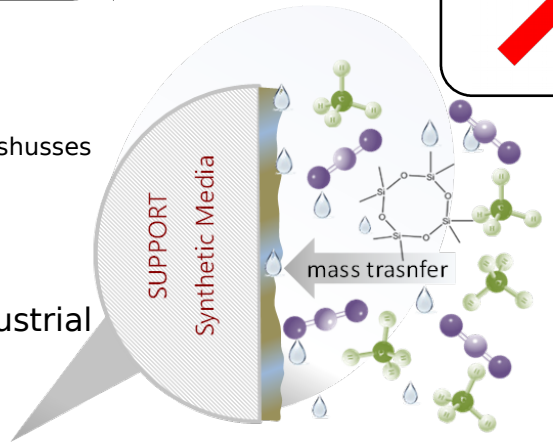
Low energy and chemicals demand

Scarce reports at **LABSCALE**

40% D4 removal at EBRT 20 min (Popat & Deshusses 2008)

Low **mass transfer** due to **low water solubility**

EBRTs that high would not be viable at industrial scale



High removal efficiency

Mature technology

Frequent replacement of **exhausted** material

Disposal of spend carbon as **hazardous waste**

OPERATING COSTS

I **Anoxic biodegradation** of siloxane **D4** in a lab-scale biotrickling filter.

II **Co-treatment** of siloxanes and other biogas impurities in the BTF

III **Influence of the EBRT** upon the compounds removal in order to optimize the performance of the system.

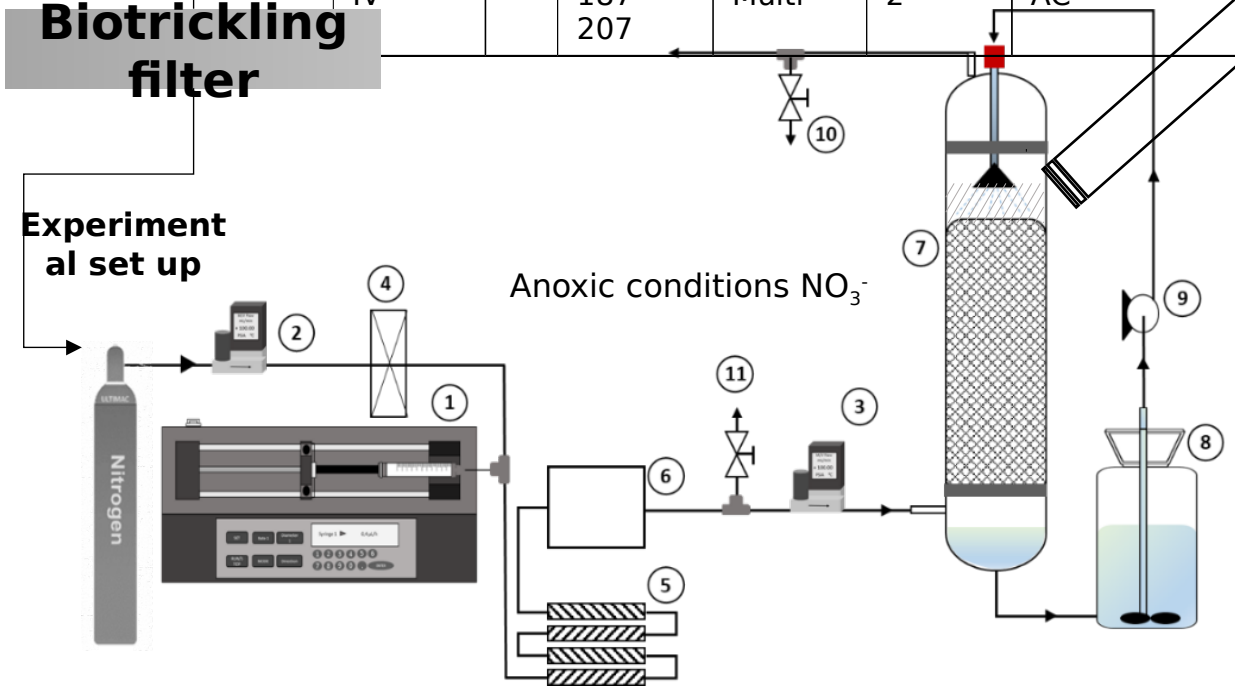
IV Role of an **activated carbon layer** → enhancing the mass transfer of water insoluble compounds

Operating conditions

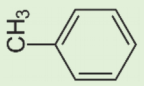
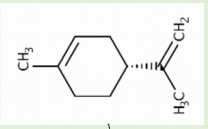
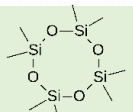
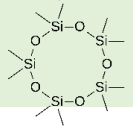
Stage		Period [days]	C-Source	EBRT [min]	Packing media
I		0-42	D4	14.5	Lava rock
II	-1	43-85	Multi	14.5	Lava rock
	-2	86-107	Multi	10.1	Lava rock
	-3	108-128	Multi	7.3	Lava rock
	-4	129-152	Multi	4	Lava rock
III		153-186	Multi	12	Lava rock+AC
IV		187-207	Multi	2	AC

Biotrickling filter

Experimental set up



Supplementation of the packing bed with 20% of a Wood-based H_3PO_4-**ACTIVATED CARBON**

Compound	Formula	MW [g mol^{-1}]	Solubility [mg L^{-1}]	Inlet conc. [mg m^{-3}]
Hexane		86	9.5	375 ± 18
Toluene		92	526	24 ± 2
Limonene		136	13.8	220 ± 11
D4		297	0.056	54 ± 3
D5		371	0.017	102 ± 4

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I		0-42	D4	14.5	Lava rock
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III		153-186	Multi	12	Lava rock+AC
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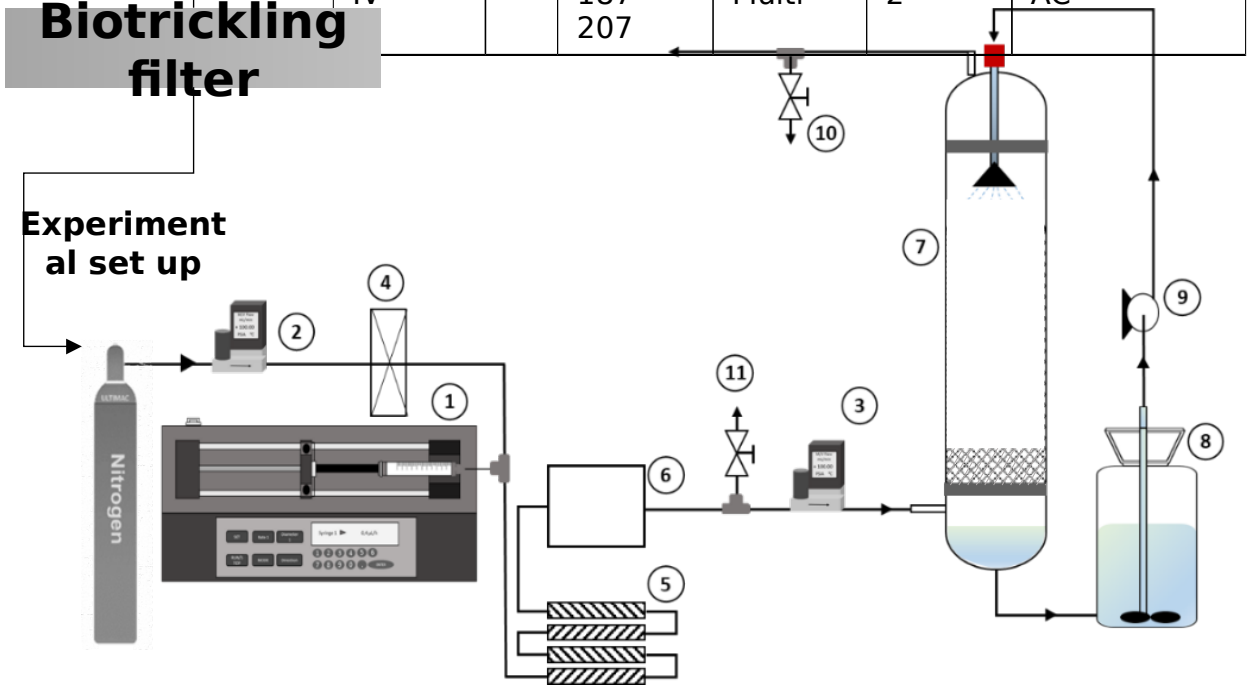
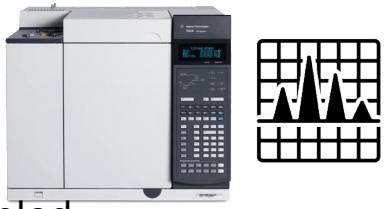
Biotrickling filter

Experimental set up



Analytical procedures

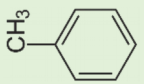
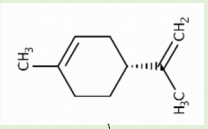
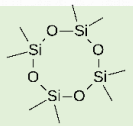
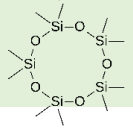
Gas streams – Gas chromatography
- Flame Ionization detector (FID)
- Mass spectrometry (MS)



Silicon compounds
- Total Silica: Inductively coupled plasma-optical emission spectroscopy (ICP-OES)
- Silicic acid: colorimetric test

NO_3^-, NO_2^-: Ion chromatography with conductivity detector

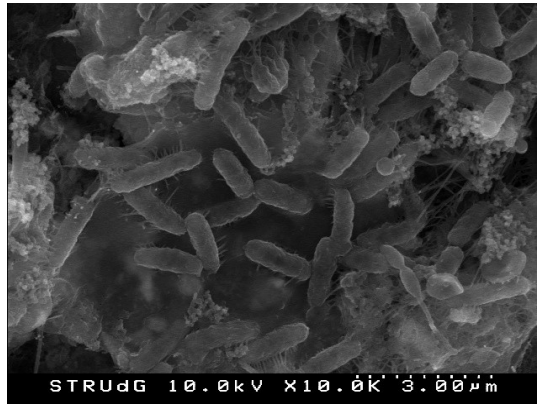
Biomass: Scanning electron microscopy (SEM)

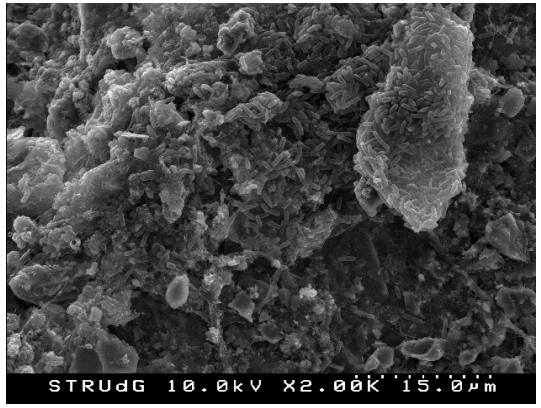
Compound	Formula	MW [g mol^{-1}]	Solubility [mg L^{-1}]	Inlet conc. [mg m^{-3}]
Hexane		86	9.5	375 ± 18
Toluene		92	526	24 ± 2
Limonene		136	13.8	220 ± 11
D4		297	0.056	54 ± 3
D5		371	0.017	102 ± 4

BTF operation – stage I: D4 only

Average 14% removal efficiency

SEM analysis of the lava rock





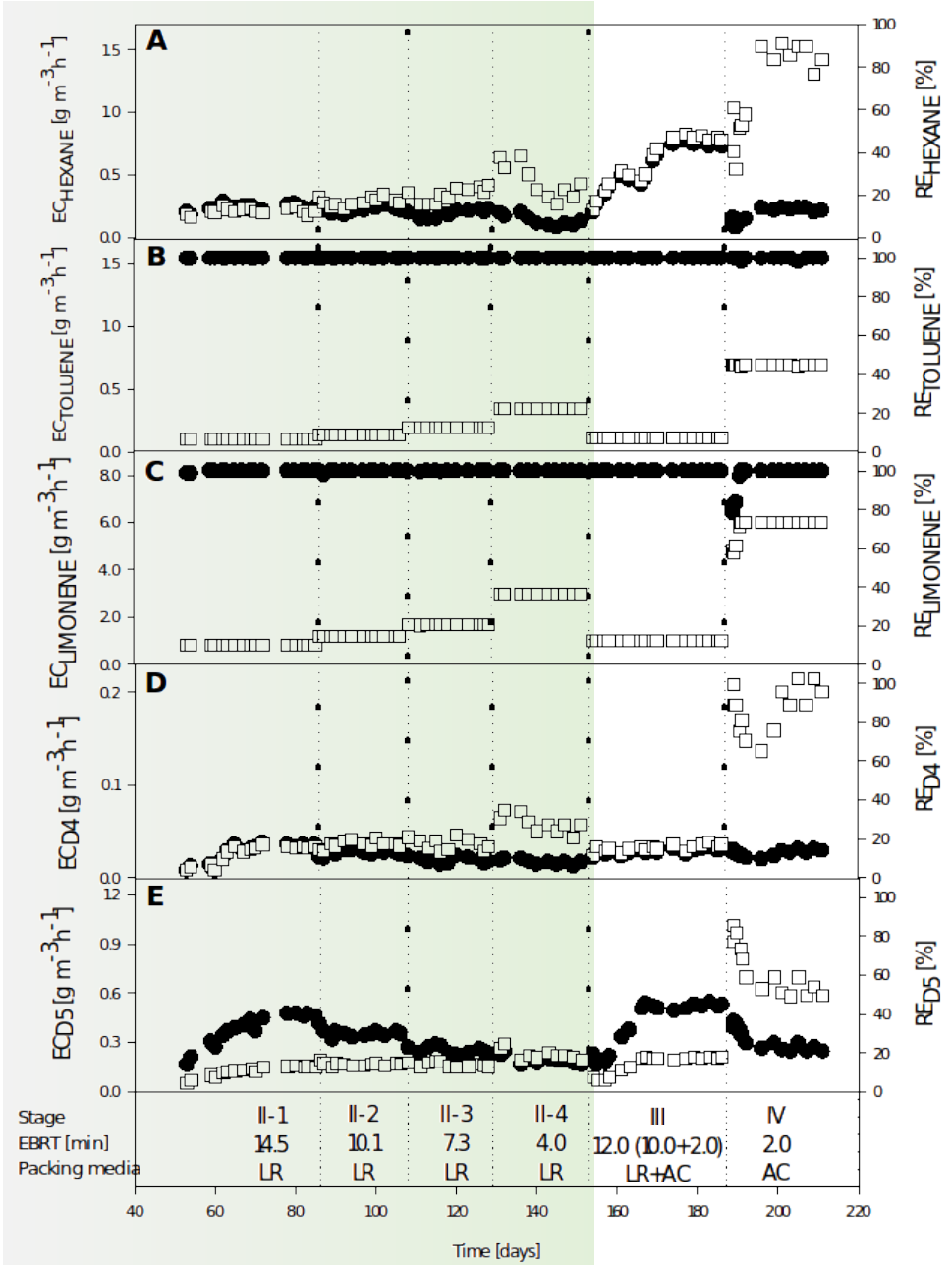
BTF operation – stage II: multicompound

Limonene and toluene 100% RE at all EBRTs

Max. 16% RE of hexane at longest EBRT

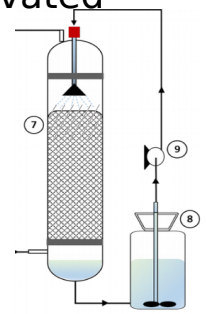
D5 RE from 15 to 37% at EBRT 4 to 14.5 min

D4 removal ranged 8-14%



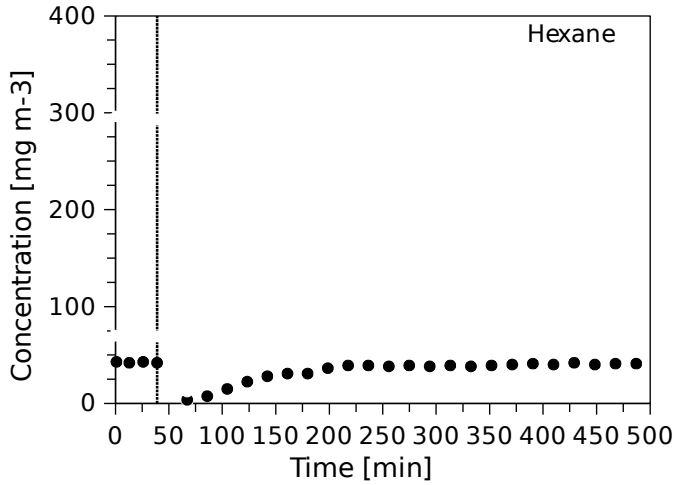
BTF operation – role of the AC

BTF packing bed supplemented with activated carbon



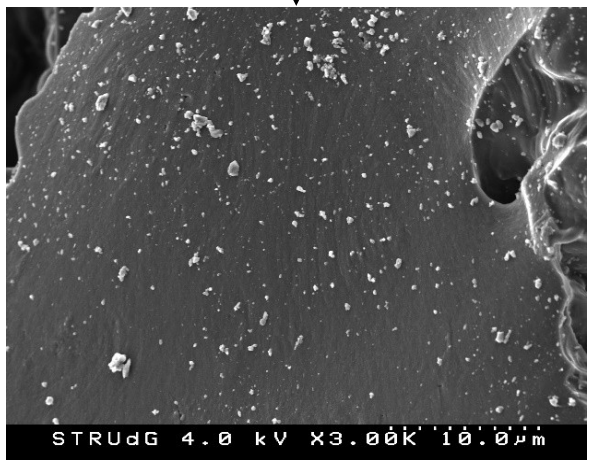
After 20 days:

- D5 and hexane REs increased up to 45 and 44%, respectively
- Higher presence of silanediols, catalytic AC

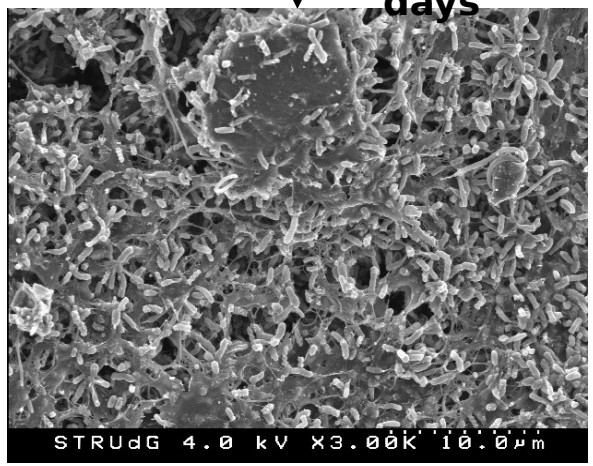


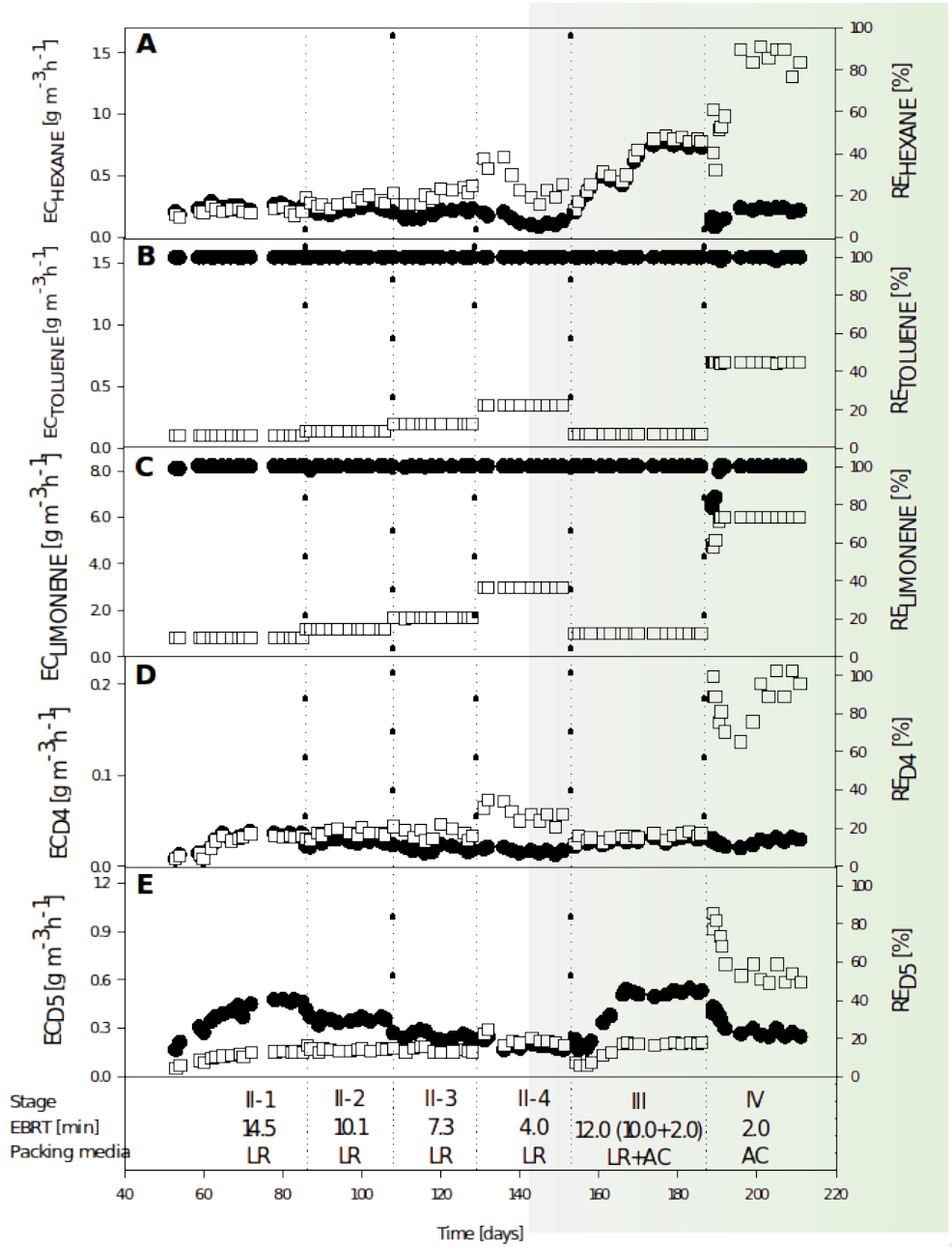
Activated carbon SEM images

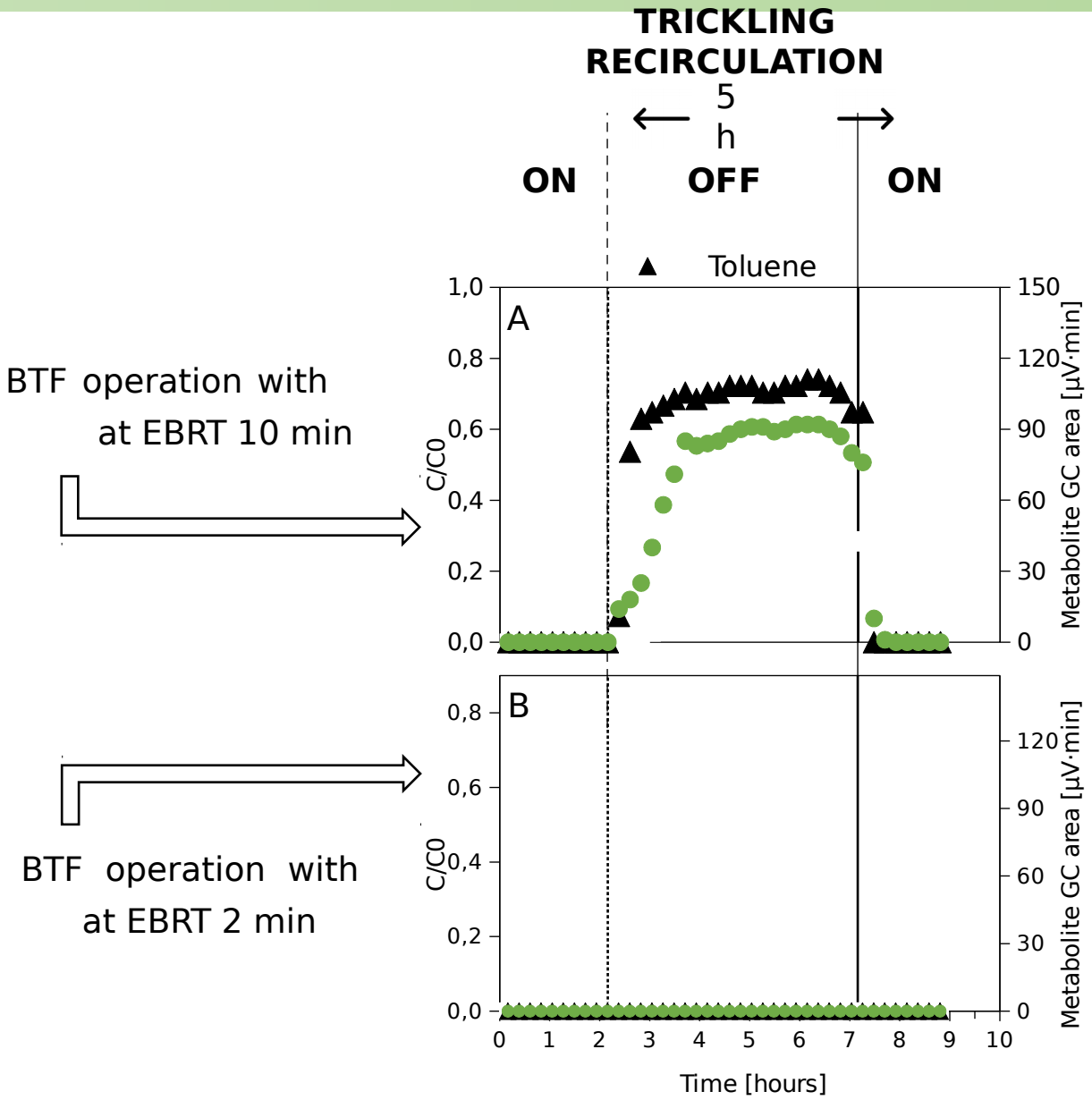
BEFORE



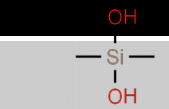
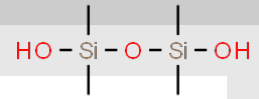
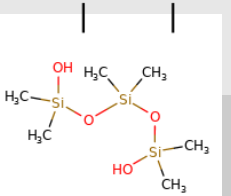
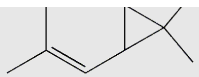
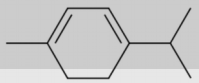
AFTER 30 days







METABOLITES IDENTIFICATION

Metabolite	Formula	MW [g mol^{-1}]	Analytical ions m/z [abundance]
Dimethylsilanediol [DMSD]		92	77 [99.9] 45 [14.6] 78 [6.6]
Tetramethyl-1,3-disiloxanediol		166	133 [99.9] 151 [71.2] 135 [22.6]
Hexamethyl-1,5-trisiloxanediol		240	207 [99.9] 208 [21.1] 209 [17.0]
2-careen		136	93 [99.9] 121 [96.8] 136 [66.9]
α-terpinene		136	121 [99.9] 93 [84.7] 136 [42.6]
P-cymene		134	119 [99.9] 91 [34.7] 134 [23.8]

- A **complete removal** of toluene and limonene was accomplished by an anoxic lab-scale BTF inoculated with *Pseudomonas sp*. **even at short EBRTs**.

- The removal of **hexane, D4 and D5** was correlated to their Henry's law coefficients, which indicated that mass transfer limitations **challenged** their abatement in the BTF.

- The supplementation of the BTF packing bed with **Activated Carbon** enhanced the transference of **hexane and D5** to the microbial community.

- AC supplementation enabled BTF operation at **reduced EBRTs** while displaying a **high robustness** towards interruptions in the trickling irrigation.

Biotrickling filtration as sustainable technology for biogas upgrading to renewable fuel

Thank you for your attention!

28th June, 2019

Universitat de Girona

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