Simultaneous removal of ammonium from landfill leachate and hydrogen sulphide from biogas using a two-stage oxic-anoxic system

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8th International Conference on Sustainable Solid Waste Management Thessaloniki, Greece, 23 - 26 JUNE 2021

Education:

- Chemical and PhD degrees by the University of Sevilla

Current Position

- Full Professor of Chemical Engineering

Research interest:

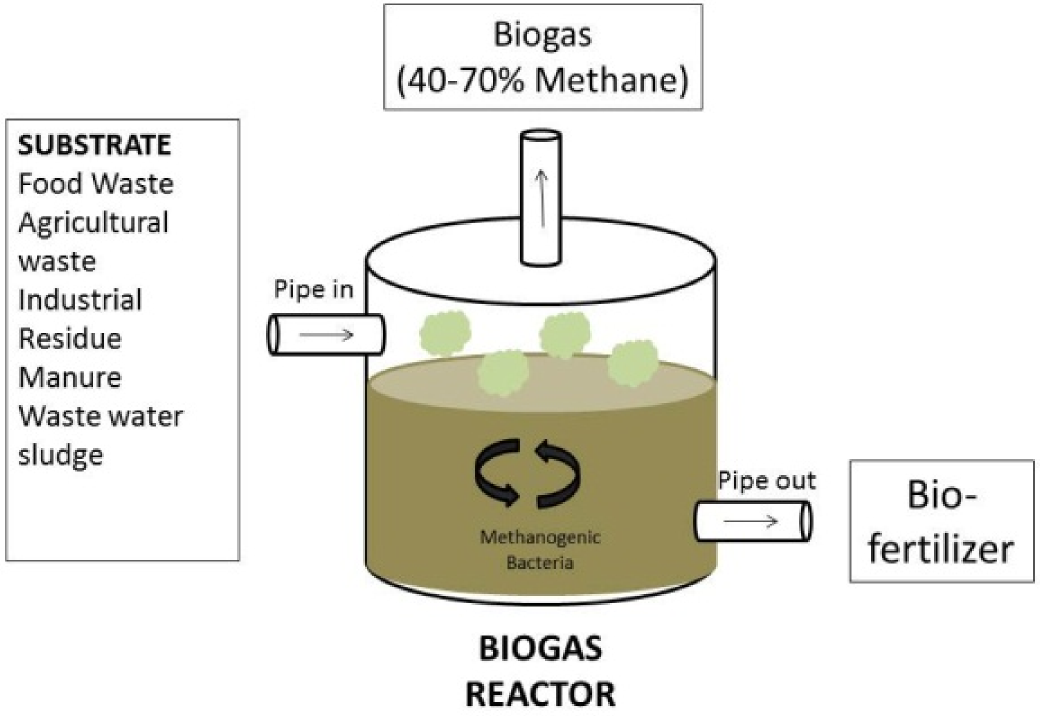
- Effluent gases biofiltration, such as air (odour removal) and biogas (desulfurization and upgrading)
- Kinetics Modelling. Optimization.
- Bioremediation of high values metals

Publications:

- 130 scientific papers
- Supervised 13 Ph.D thesis
- more than 50 conference proceedings

Reactores biológicos y enzimáticos

Biogas production

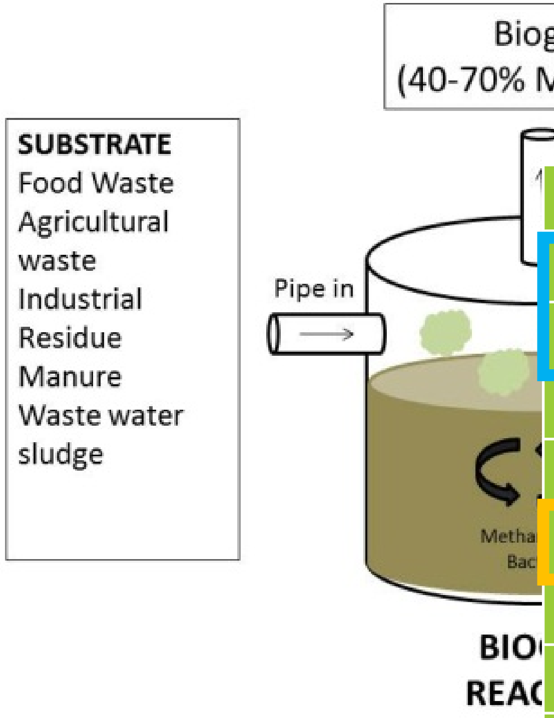


- **Production:** Biodegradation of organic matter by the action of microorganisms under anaerobic conditions.

Biogas production

1.- Dangerous for the environment (SO_2 emissions)

2.- Strongly corrosive to metal parts



H_2S removal/reduction essential

Compound	WWTP sludge	Agricultural waste	Landfill
CH_4	50-80%	50-80%	45-65%
CO_2	20-50%	30-50%	34-55%
Water	Saturated	Saturated	Saturated
H_2	0-5%	0-2%	0-1%
H_2S	0-10.000ppmv	100-700ppmv	0,5-700ppmv
NH_3	Traces	Traces	Traces
O_2	0-2%	0-2%	0-2%
CO	0-1%	0-1%	Trazas
N_2	0-3%	0-1%	0-20%
VOC	Traces	Traces	Traces
Siloxanes	-	-	50mg m^{-3}

- **Production:** Biodegradation
of microorganisms under ar

Anoxic biodesulfurization

- **Widely studied in BTFs**
- **Elemental sulfur accumulation**

- Blockages
- Technical stop
- Reinoculation
- Operating cost increase

- **Sulfate is not desirable because it can be reduced again to H_2S in anaerobic conditions**

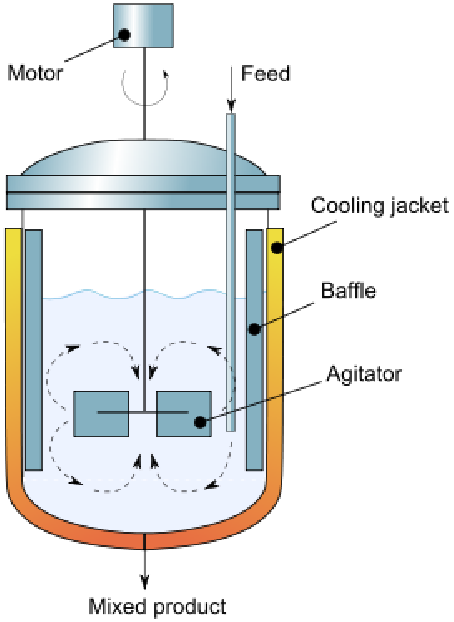
$$SO_4^{=} + \text{organic matter} \xrightarrow[\text{bacteria}]{\text{anaerobic}} S^{=} + H_2O + CO_2$$

¿Solution?

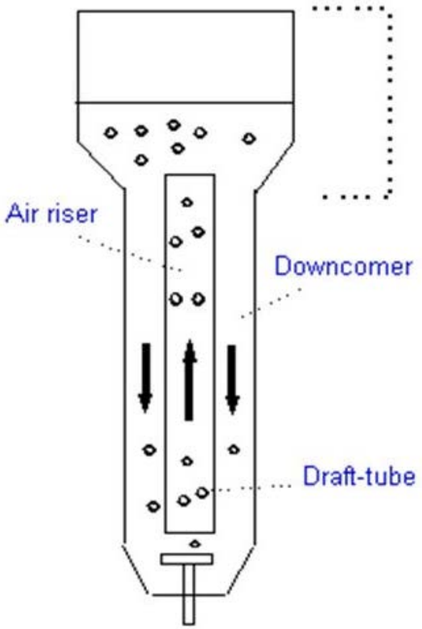
Use of suspended biomass bioreactors

Allow S^0 recovery

CSTBR



Gas-lift

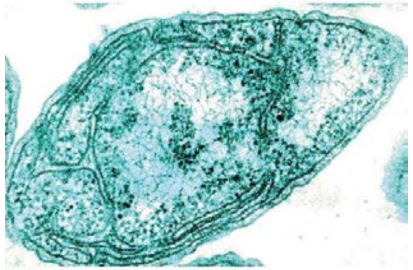


Effluent rich in nitrate a/o nitrite from a biological source

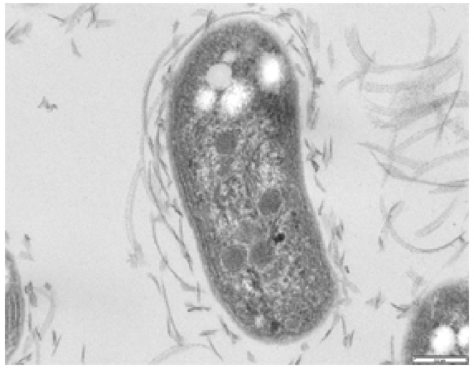
- **Nitrification**

$$NH_4^+ + {}^3/_2\, O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + {}^1/_2\, O_2 \rightarrow NO_3^-$$



Nitrosomonas europaea



Nitrobacter winogradskyi

NH_4^+- rich effluents

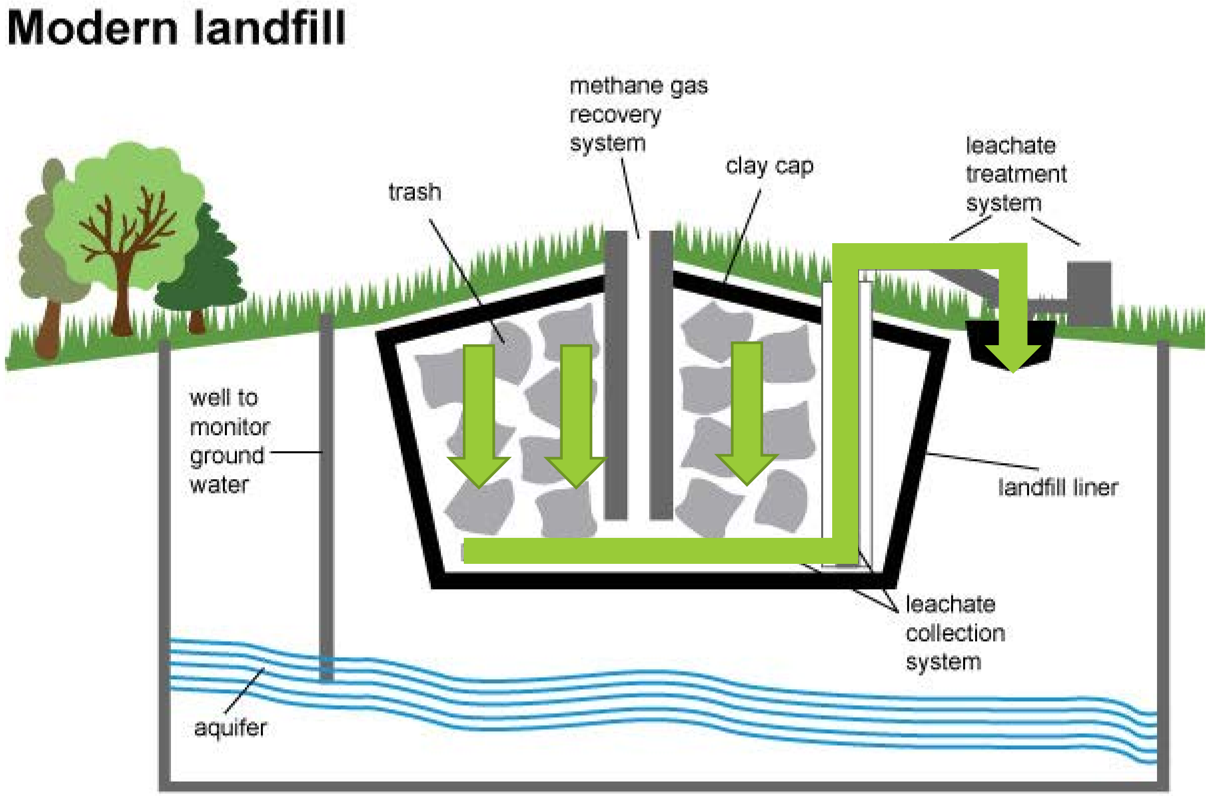
Digestate

Landfill leachate

Landfill leachate

- **Liquid effluents generated by water percolating through the waste deposited in a landfill site**

- **Characteristics:**
  - **(i) High variability**
  - **(ii) High ammonium content**
  - **(iii) Presence of toxic and non-biodegradable compounds**



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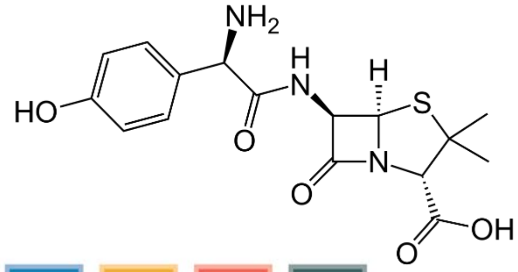
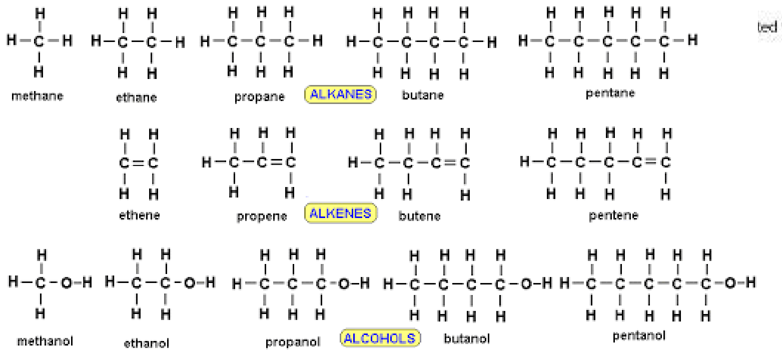
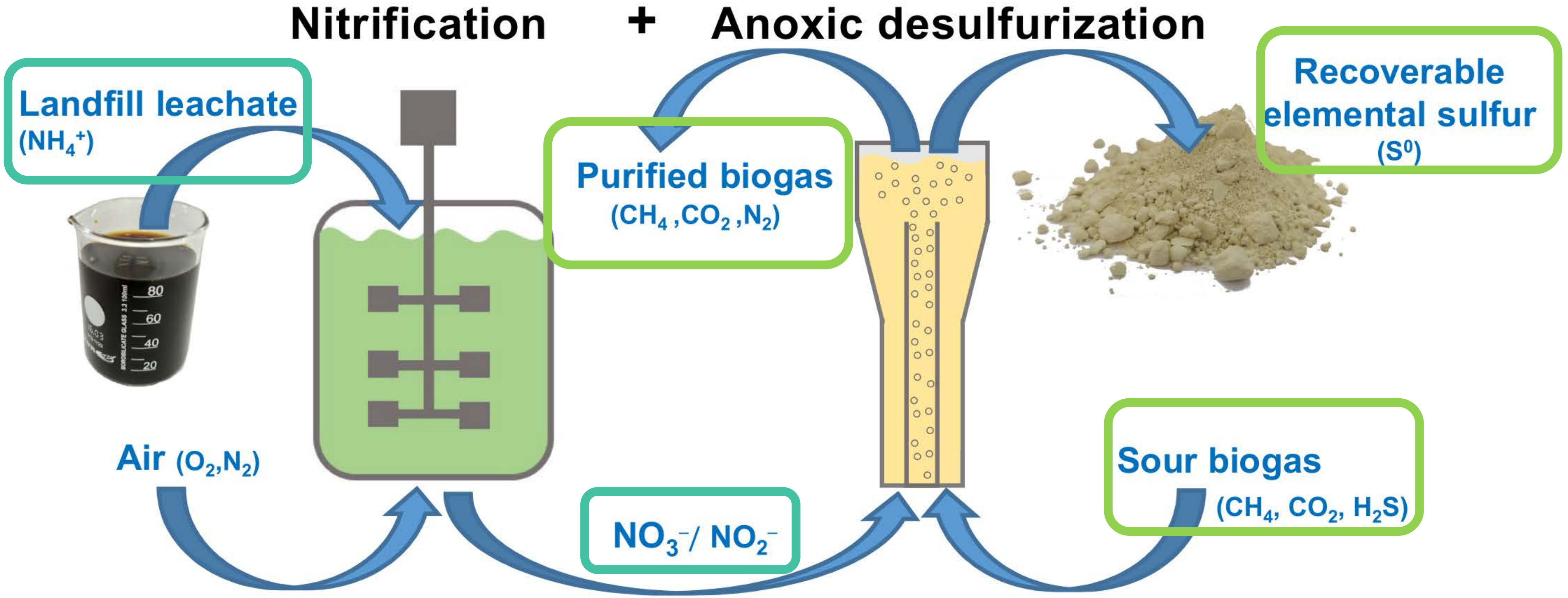




Integrated system of a nitrification bioreactor with anoxic biodesulfurization SBB



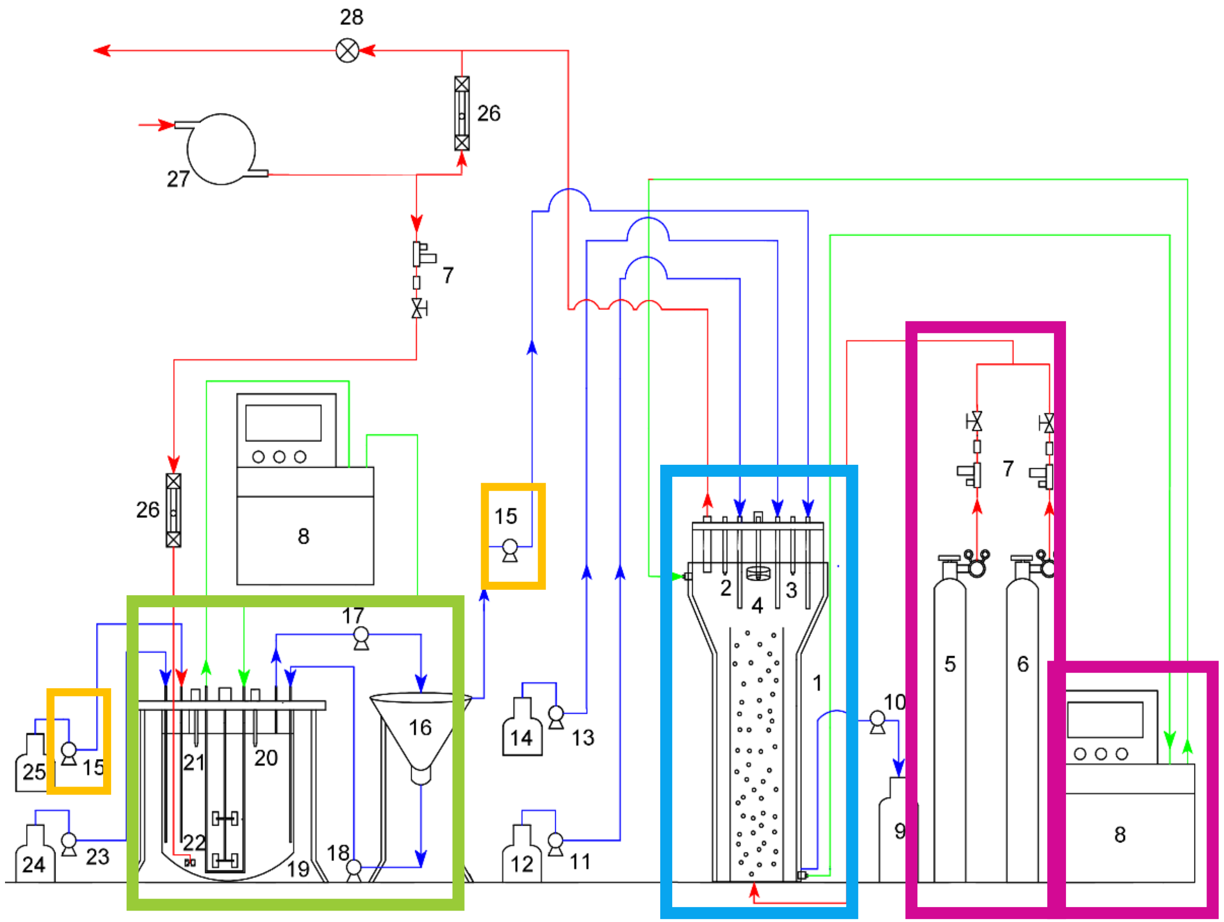
$$NH_4^+ + {}^3/_2\, O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

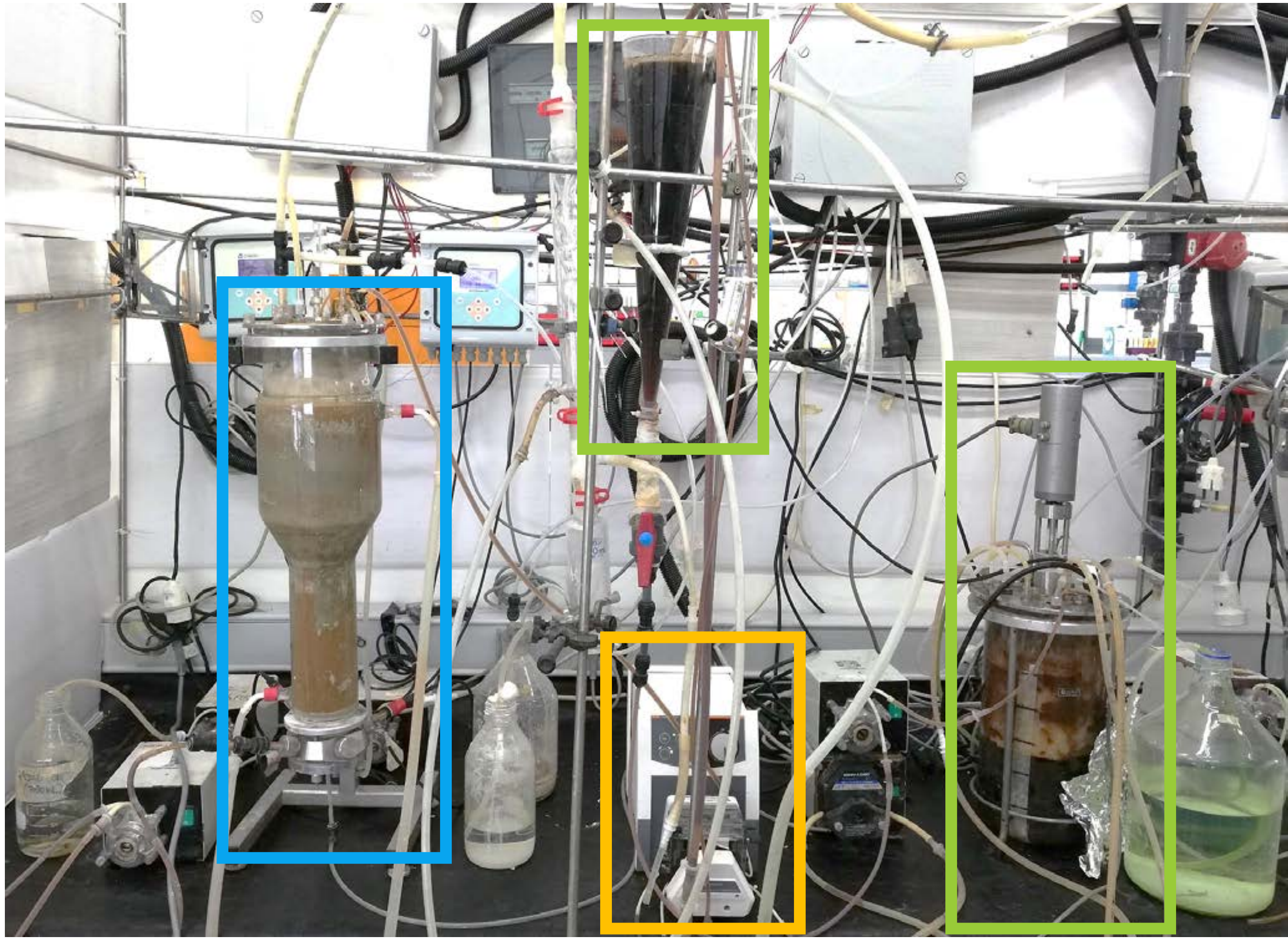
$$NO_2^- + {}^1/_2\, O_2 \rightarrow NO_3^-$$

$$5\, HS^- + 2\, NO_3^- + 7\, H^+ \rightarrow 5\, S^0 + N_2 + 6\, H_2O$$

$$S^{2-} + 0.67\, NO_2^- + 2.67\, H^+ \rightarrow S^0 + 0.33\, N_2 + 1.33\, H_2O$$

Experimental Set-up



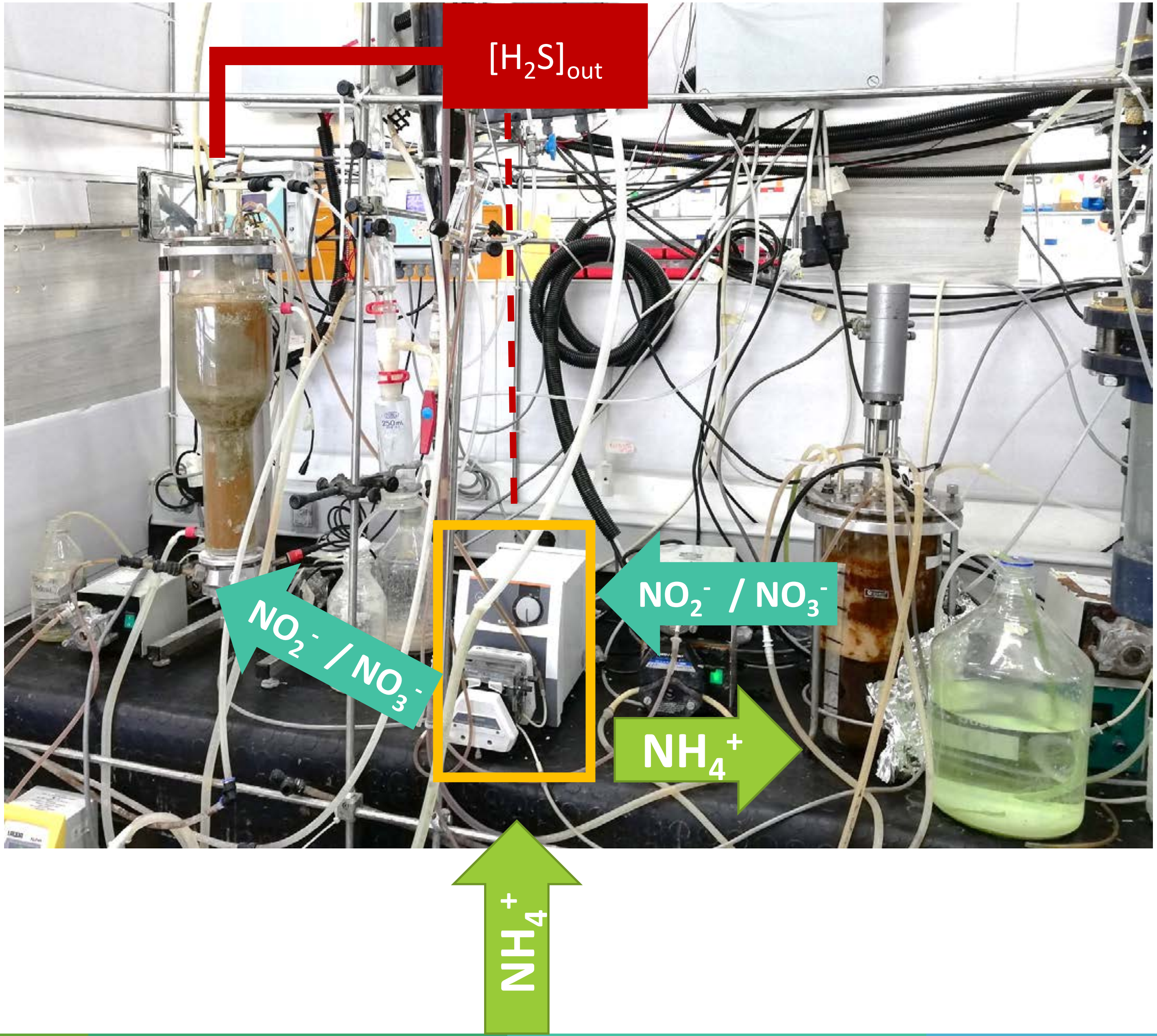


Control strategy

All experiments under a PI control using:

PV: $[H_2S]_{out}$

MV: Qs nitrification biorreactor effluent(NO_2^- /NO_3^-)



Experimental conditions

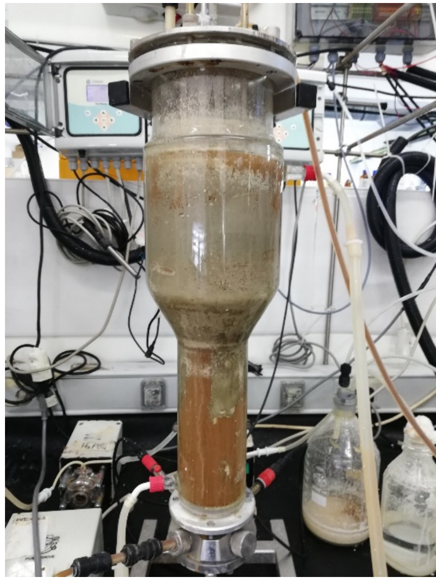
Exp.	GRT (s)	IL ($gS\text{-}H_2S\ m^{-3}\ h^{-1}$)	NH_4^+ Source*	$[H_2S]_{in}$ (ppm_v)
1	104	41	SM and LL	900
	88	48		
	56	76		
	41	104		
2	79–41	56–104	SM and LL	
3	41	100–150	LL	860 – 1300

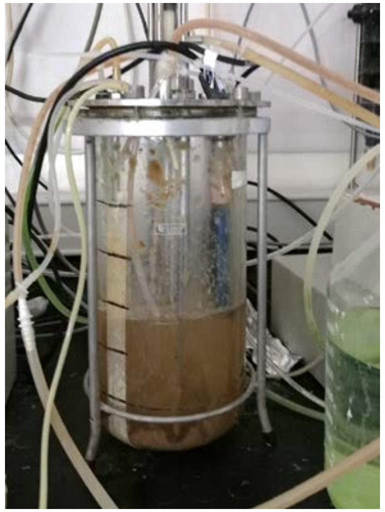
*NH_4^+ concentration = 1100 mg $N\text{-}NH_4^+\ L^{-1}$

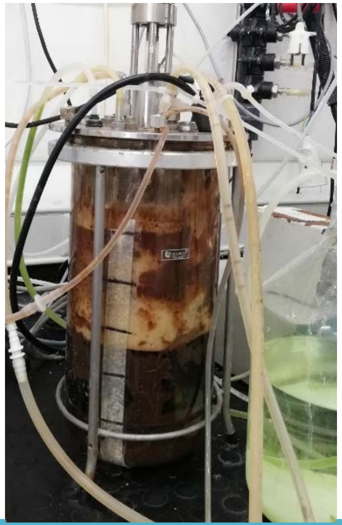
Realistic H_2S concentration in biogas (900 ppm_v) and NH_4^+ in both effluents (1100 mg $N\text{-}NH_4^+\ L^{-1}$)
Shaha et al. (2020); Costa et al. (2019)

SM
Synthetic medium

LL
Landfill leachate

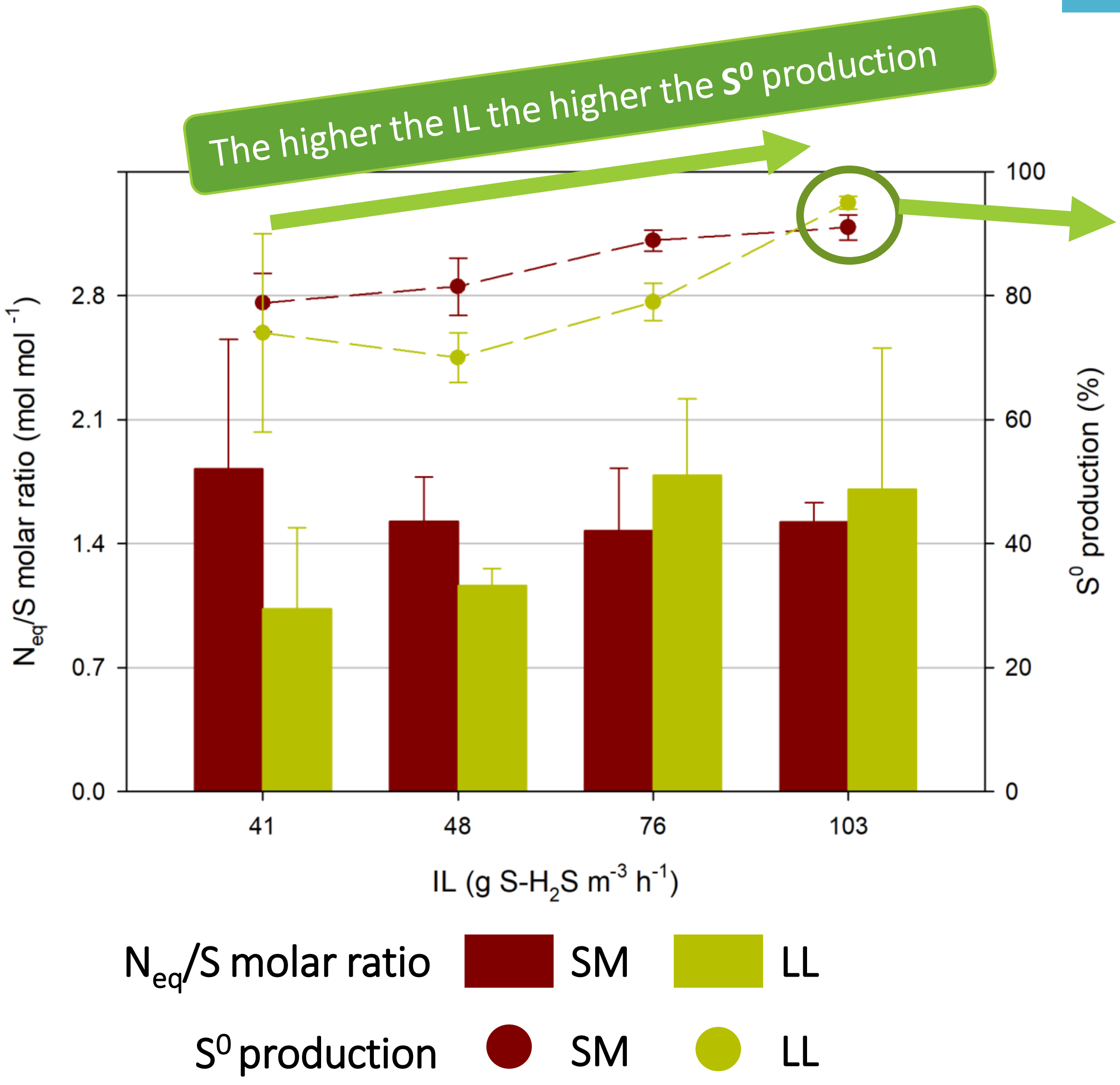






Experiment 1

GRT	N_{eq}/S molar ratio (mol mol^{-1})		S^0 production (%)	
	SM	LL	SM	LL
104	1.8 ± 0.7	1.0 ± 0.5	79 ± 5	76 ± 14
88	1.5 ± 0.2	1.2 ± 0.1	81 ± 5	70 ± 4
56	1.5 ± 0.4	1.8 ± 0.4	89 ± 2	86 ± 3
41	1.5 ± 0.1	1.7 ± 0.8	91 ± 2	95 ± 1

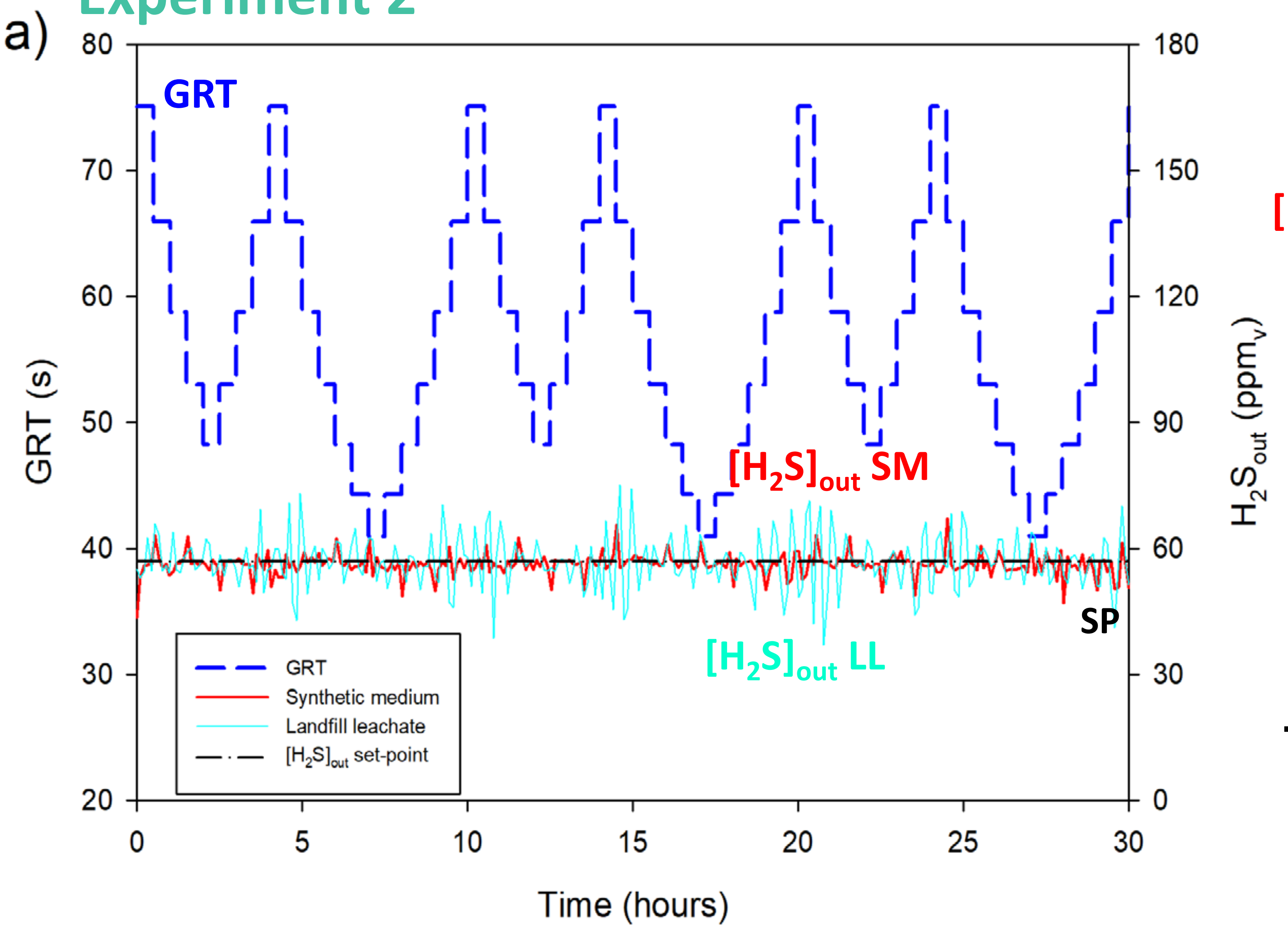


SM – S^0 % = 91 ± 2%

LL – S^0 % = 95 ± 1%

N_{eq}/S molar ratio of
1.7 ± 0.8 mol mol^{-1}

Experiment 2



The PI control works correctly with both ammonium sources.

$[H_2S]_{out}$ SM 56.4 ± 2.7 ppm_v

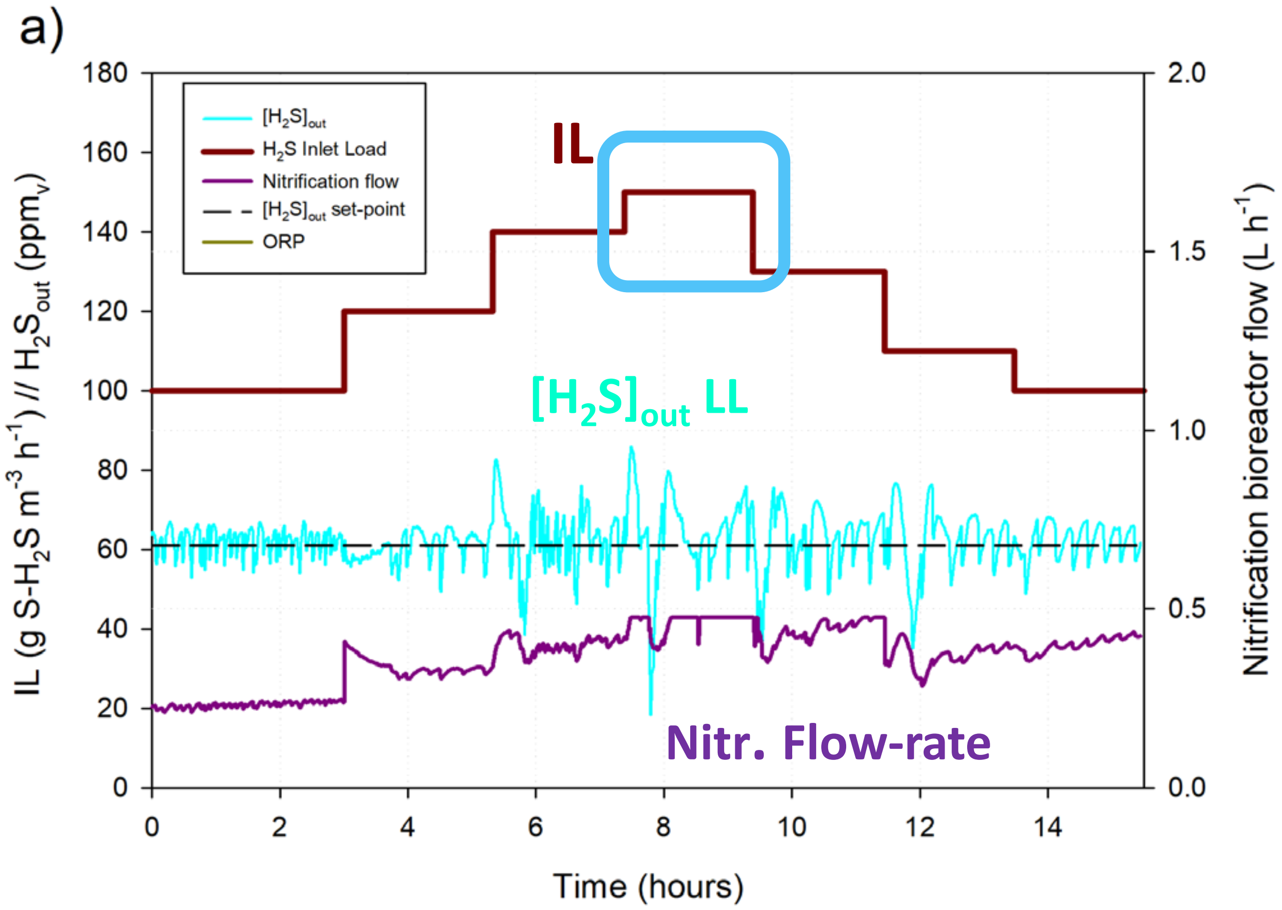
Q SM 0.08 ± 0.01 L h^{-1}

$[H_2S]_{out}$ LL 56.8 ± 6.1 ppm_v

Q LL 0.18 ± 0.04 L h^{-1}

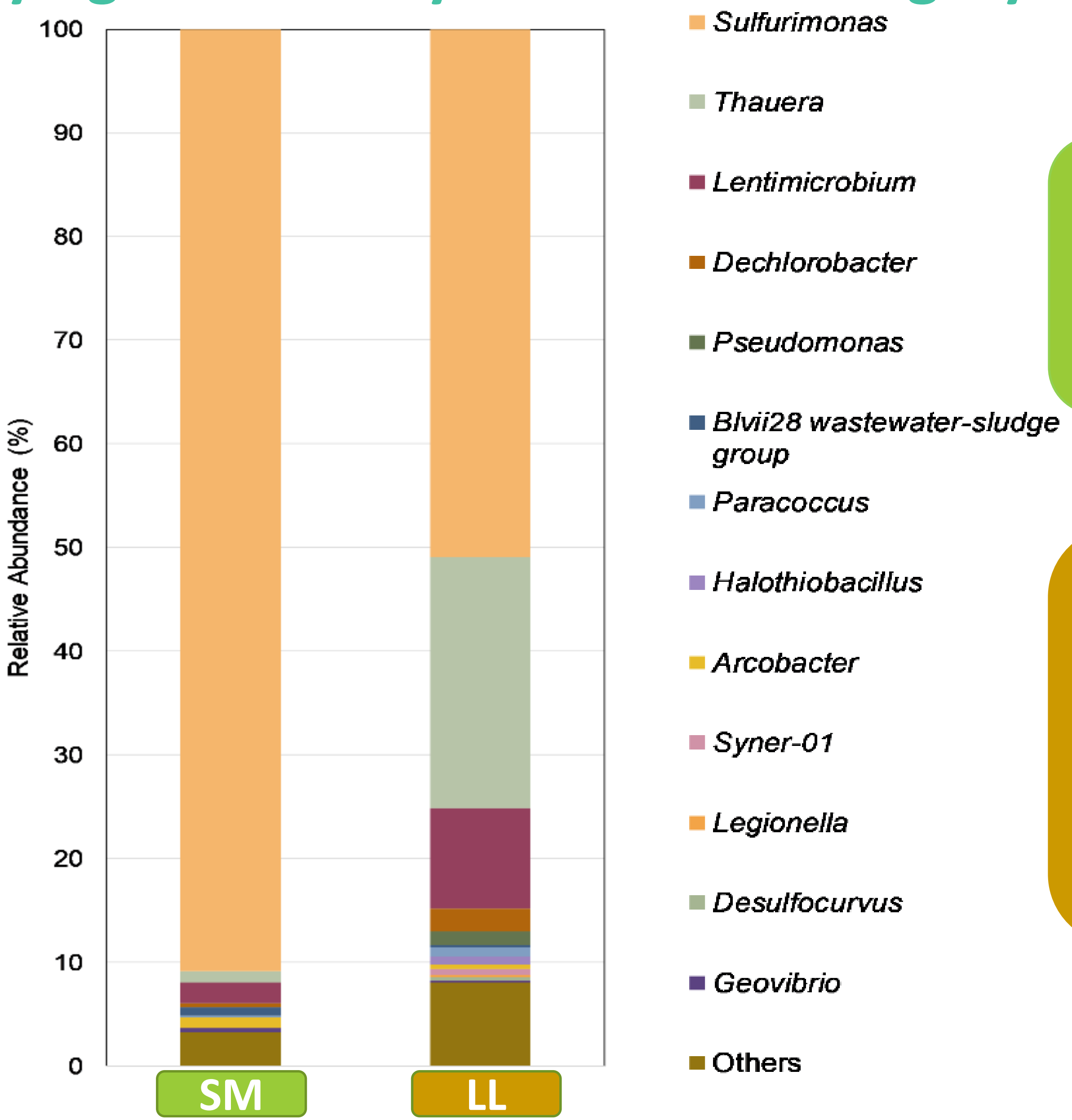
— · — $[H_2S]_{out}$ Set-point

Experiment 3



(EC= 141.18 gS-H_2S m^{-3} h^{-1}; RE = 95.0%)

Phylogenetic analysis– Genera category



SM

Sulfurimonas = **91.8%**
Lentimicrobium = **2.0%**
Thauera = **1.1%**
Arcobacter = **0.9%**
…

LL

Sulfurimonas = **50.9%**
Thauera = **24.2%**
Lentimicrobium = **9.7%**
Dechlorobacter = **2.2%**
Pseudomonas = **1.2%**
Halothiobacillus = **0.7%**
…

Sulfurimonas
Común en biorr. de desnit. autótrofa
Zeng et al. (2019), Liu et al. (2019), Maestre et al. (2009)

Useful for bioaugmentation strategy

Thauera
Común en biorreactores tratando LL
Yin et al. (2019)
Saleem et al. (2018)

- The operation of a desulfurization bioreactor with suspended biomass demonstrated its robustness using nitrite/nitrate from the oxidation of different ammonium sources such as synthetic medium and intermediate landfill leachate.
- The operation of the system demonstrated the possibility of using a nitrified effluent obtained from an intermediate landfill leachate which reduces the operating costs of the anoxic desulfurization. This novel technology can solve the problem caused by the presence of H_2S in the biogas while reducing the amount of leachate accumulated in the landfills.
- *Sulfurimonas* stands out as the most common genus in the desulfurization bioreactor, followed by the *Thauera* and *Lentimicrobium* genera.
- Definitely, the results obtained in this study provide a promising and ecologically efficient technology for producers of biogas in landfills, thus providing added value with less impact.