Sustainable Biogas Purification System in Landfills and Municipal Solid Waste Treatment Plants: The Greek case study

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Abstract

The use of **biogas for energy production** is increasing at EU level due the lower cost and associated reduction of greenhouse gas (GHG) emissions compared to fossil fuels. Conventional **physical-chemical techniques** are able to reduce the H_2S concentration on biogas but they have a great impact on the environment. Typical current desulfurization technologies involve the use of large amounts of **chemical reagents**, the production of **secondary wastes** or **high energy costs**. These drawbacks hinder the use of biogas as fuel in most of the facilities where this combustible is produced. BiogasNet technology proposed the above system:

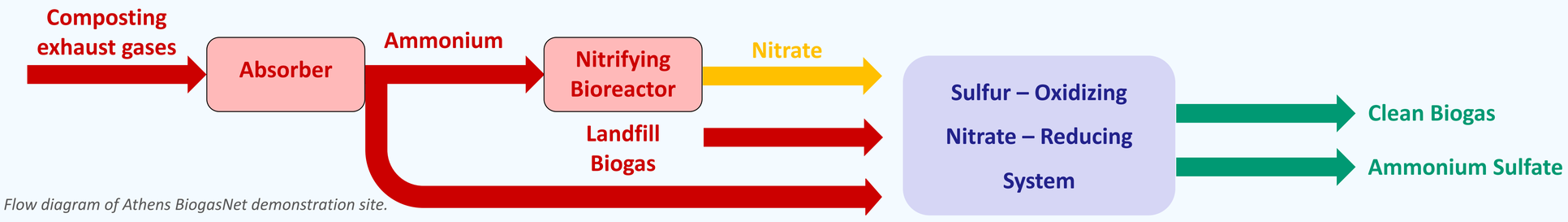


Figure 1: Flow diagram of Athens BiogasNet demonstration site.

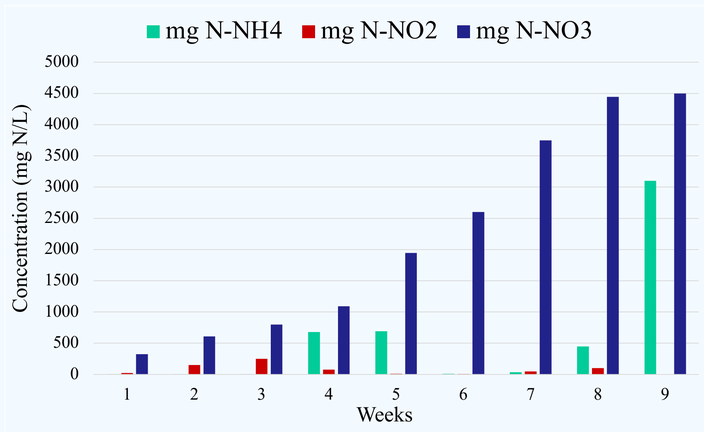
Results

Nitrification Stage

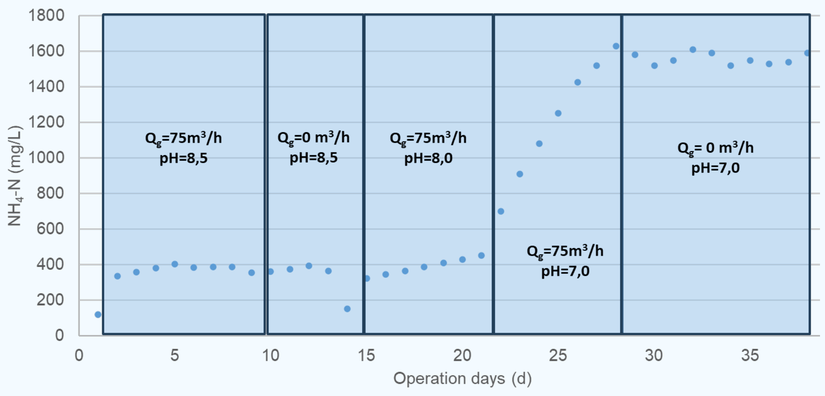
Nitrification Bioreactor Operation with Synthetic Medium

A 9 week operation was conducted in a working volume 1000L. For the first 5 weeks up to 115g NH_4-N/m^3/d, the nitrification bioreactor was operated in fed batch mode.

- ✓ 1-3 weeks IL=50 g NH4-N/m3/d successful ammonium bioconversion.
- ✓ 4-5 weeks IL=115 g NH4-N/m3/d led to increase in the N-NH4 concentration.
- ✓ 6 week no feeding for N-NO3 total bioconversion .
- ✓ 7-9 weeks, continuous mode operation with a nitrogen load to 160 g NH4-N/m3/d resulted in lower nitrification yields but further accumulation of nitrates.



Ammonium Scrubber Operation



Average ammonia gas inlet of 70-110ppm in a working volume which was controlled in 65L.

After these 40 days of operation, steady state (SS) conditions were achieved and the absorbed nitrogen was fed to the bioreactor.

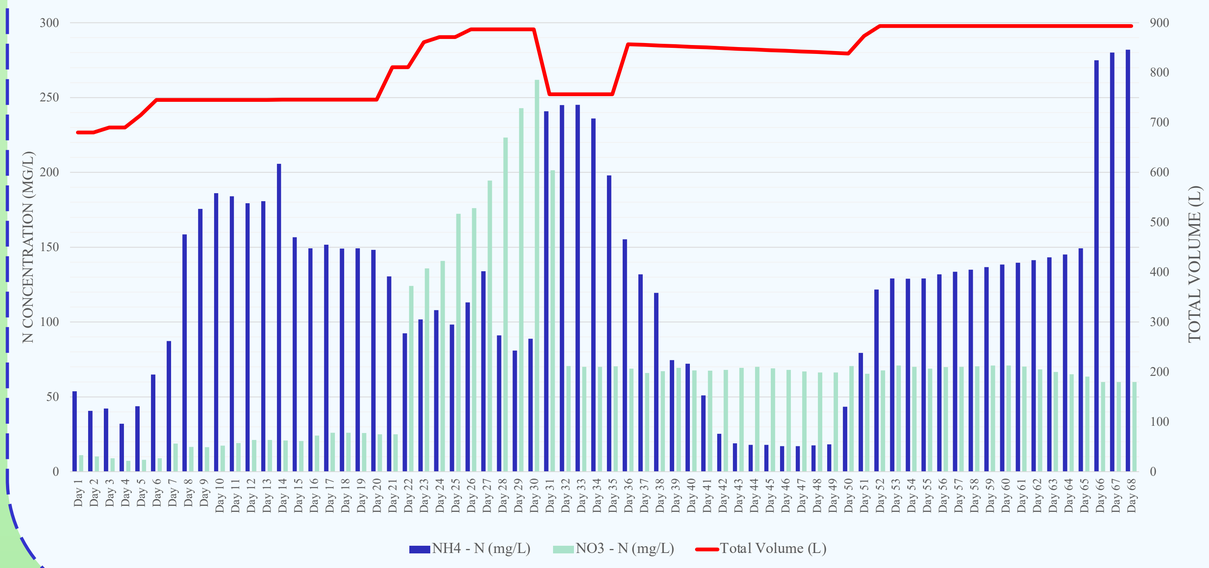
SS operating conditions:

- Composting gases flow rate 75m3/h
- pH = 7.0
- Daily transferred liquid 40L to the bioreactor.

Nitrification Bioreactor Operation with Ammonium Scrubber Feeding

Fed batch operation was applied, using the liquid from the scrubber as nitrogen source.

- ✓ During the first 18 days, low nitrification rates were observed, although ammonia nitrogen was converted to nitrate nitrogen
- ✓ Additional inoculation improved nitrification yields significantly (Day 19). The lag phase was very short, consuming most of the available ammoniacal nitrogen (day 49)
- ✓ Temperature fall to below 10oC due to heating failure at day 50 did not result in a respective nitrification efficiency then on
- ✓ Days 68-115 are not depicted due to low nitrification rates in low temperature operation. Nitrification efficiency during this phase was very low, although not zero.



Desulfuration Stage

Operation of Anoxic Scrubber with Synthetic Medium

Inoculum (L)	Mineral Medium (L)	H2S source	Volume (L)
50 L anaerobic sludge	20 L (Na2CO3 40 g/L, NaNO3 68 g/L, NH4Cl 27 g/L, NPK 3 L)	Chemical (Na2S)	202.02

1st Trial

- ✓ Sulfate concentrations increased gradually over the six-day period, reaching a peak of **1422.81** g (in mass terms) on **Day 5.**
- ✓ The observed increase in sulfate (SO4) concentrations aligns with the expected microbial reduction of sulfur compounds
- ✓ The added H2S from the Na2S solution served as a substrate for sulfur-reducing microorganisms.

Time (d)	NO_3-N (g/L)	SO_4 (g/L)	NH_4-N (g/L)	TC (g/L)	IC (g/L)	pH
1	4.62	3.60	0.93	0.60	0.27	8.19
2	3.63	3.90	1.40	0.62	0.42	8.15
3	2.60	5.50	1.94	1.04	0.81	7.30
4	2.50	5.75	1.81	1.56	0.96	8.01
5	2.72	6.85	1.87	1.51	1.00	7.77
6	2.30	6.88	1.72	2.60	0.94	7.73

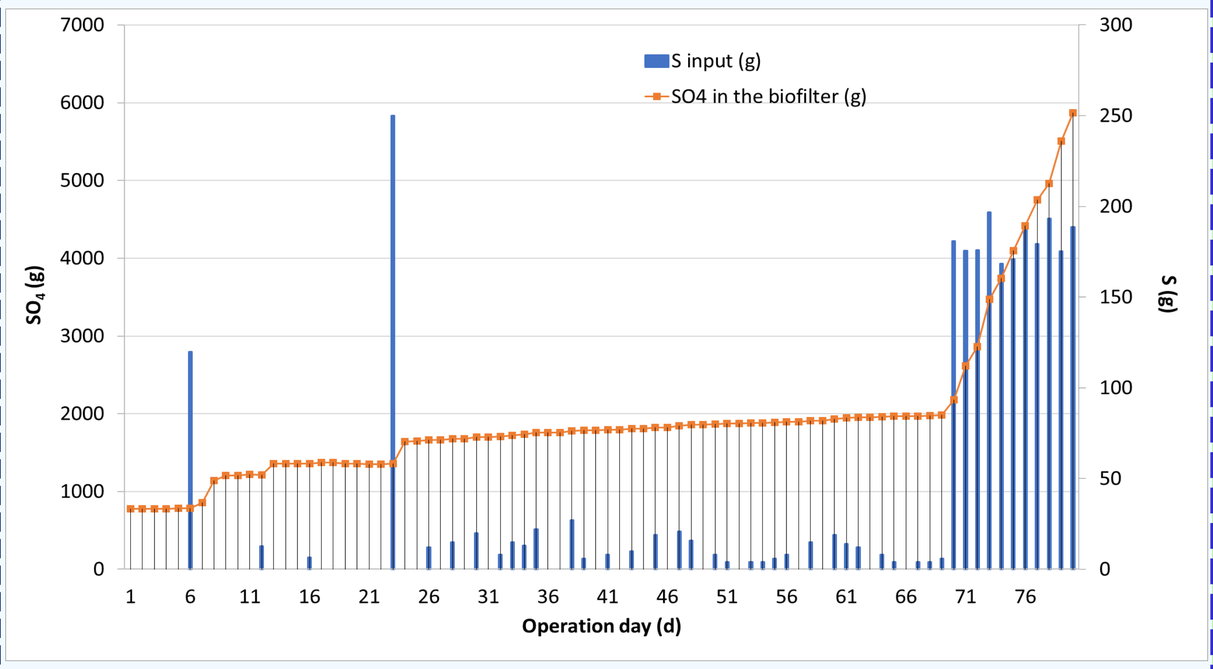
2nd Trial

- ✓ The SO4 levels are in line with the initial trial, reinforcing the reliability of the process. The system maintains a near-neutral pH, supporting microbial activities involved in sulfur and nitrogen transformations.
- ✓ The system appears robust, maintaining stable conditions for microbial transformations.

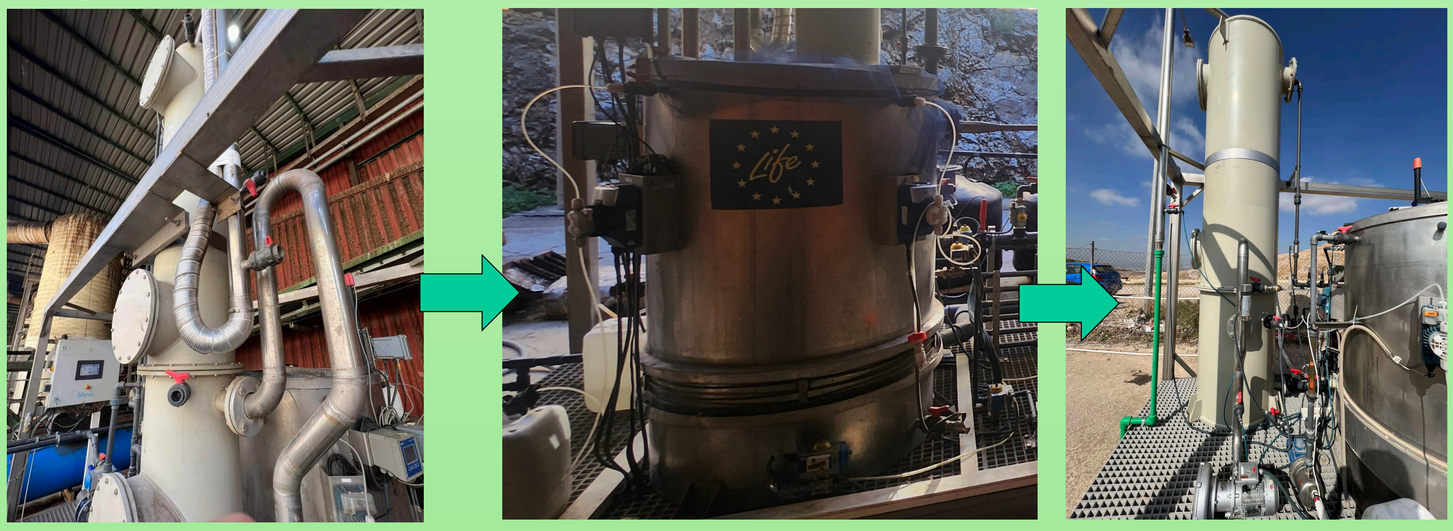
Time (d)	NO_3-N (g/L)	SO_4 (g/L)	NH_4-N (g/L)
1	5.12	5.50	1.72
2	4.25	5.63	1.90
3	3.81	6.75	2.08
4	3.05	6.70	2.28
5	3.05	6.80	2.21

The comparative analysis between the 2 trials revealed a consistent and replicable pattern in microbial activity. Noteworthy trends in nitrate, sulfate, and ammonium concentrations, coupled with stable pH levels and system volume, underscore the reliability and robustness of the experimental setup.

Operation of Anoxic Scrubber with Biogas Inlet



- ✓ The increase in biogas flow rate to 70m3/h compared to the initial conditions of 50m3/h for 72 h resulted in an increase of sulfates of 2.2g/L implying a slight decrease in the conversion efficiency.
- ✓ The conventional operating conditions of the desulphurization unit were N to S molar ratio 4:1, given that the presence of excess nitrates leads the reaction towards sulfate ions and not elemental sulfur (efficiency at around 75%).



Conclusions

- In light of these findings, the recommendation is to continue vigilant monitoring and analysis in subsequent trials, ensuring ongoing validation and refinement of microbial dynamics understanding.
- Exploration of optimization opportunities is advised, leveraging observed patterns and the system's demonstrated consistency to enhance efficiency and foster long-term sustainability.

Acknowledgements The European Commission provided financial support to carry out the research through the project LIFE BIOGASNET (LIFE18 ENV/ES/ 000426) “Sustainable biogas purification system in landfills and municipal solid wastes treatment plants”.