Cornell University
Dairy Environmental Systems Program
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PRO-DAIRY

HYDROGEN SULFIDE REMOVAL FROM BIOGAS

Part 1: Available technologies for hydrogen sulfide removal from biogas

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Biogas, a methane (CH_4) rich gas produced from anaerobic digestion of organics, is an undervalued renewable fuel. Upgrading biogas by removing impurities and concentrating CH_4 produces a cleaner, more useful fuel. While biogas can be upgraded to biomethane, also called reneweable natural gas (RNG) (>95% CH_4, see footnote), a fuel that can be compressed and injected into natural gas pipelines or used in CNG vehicles, upgrading to this level is currently cost prohibitive for most farms. More typical on-farm use of biogas is as a fuel source for boilers and engine-generator sets, where lower CH_4 levels (>50%) can be used; optimally with most of the moisture and hydrogen sulfide (H_2S) removed. Combinations of demisters, condensation sumps, and chillers can be used for dewatering. Many technologies can remove H_2S (desulfurize) biogas, and are highlighted below.

PHYSICAL/CHEMICAL REMOVAL

Several physical/chemical approaches are applicable to H_2S removal from dairy-manure derived biogas:

In-situ H_2S precipitation

Soluble iron salts (e.g. ferric chloride, iron sulfate) added to digester influent reacts in the digester vessel with H_2S to form insoluble, solid iron sulfide. This approach works best at high H_2S concentrations. *Total precipitation of H_2S is not typically cost-effective due to the expense of iron salts, but some northeastern farms do utilize the technology for H_2S reductions.*

H_2S adsorption (Iron sponge)

Other iron salts (e.g. ferric oxide, ferric oxide-hydroxide) immobilized on woodchip media can be used to adsorb H_2S. Typically, two packed reactors are operated in parallel at residence times of 1-15 min. Media can be regenerate ~2× by aeration (~33% of the adsorption capacity is lost during each regeneration). Regeneration is very exothermic and can auto-ignite woodchips if not prevented by adding moisture. The total annual capital and operating cost of an iron sponge for a 125 cfm biogas flowrate, the fuel demand for a 350 kW engine-generator set, is ~$35,000 (authors' calculations). The required media replacement frequency and cost have led most operators of large-scale anaerobic digesters to select other technologies for primary treatment. F*ew NYS farms use an iron sponge for primary treatment; best application is for secondary and backup H_2S removal.*

Membrane separation

Selective membranes that allow H_2S to permeate but retain CH_4 are being developed to concentrate and remove H_2S from biogas, *but are currently high-cost and have fouling issues that limit their usefulness for dairy-manure derived biogas at this time.*

H_2S absorption (Chemical Scrubber)

Water with chemical reagents (e.g. ferric oxide, sodium hydroxide) or organic solvents cycled continuously in spray or packed bed towers can be used to rapidly, chemically absorb H_2S from biogas at high efficiencies. Wastewater is generated that requires treatment. Depending on the absorbent, sulfur recovery and absorbent regeneration is possible. *H_2S chemical scrubbers are typically used for high-concentration industrial effluents (e.g. oil refinery sour gases) and are not typically cost-effective for farm-scale biogas systems.*

* According to the American Biogas Council there is currently no purity standard for biomethane. Globally CH_4 levels as low as 80% are used by some countries, though levels > 95% are used by many European countries and Australia.

BIOTECHNOLOGIES

Sulfur oxidizing bacteria (SOB) which feed on H_2S (*see Part 2 of this Series*) can be harnessed to remove H_2S from biogas.

In-situ biological desulfurization

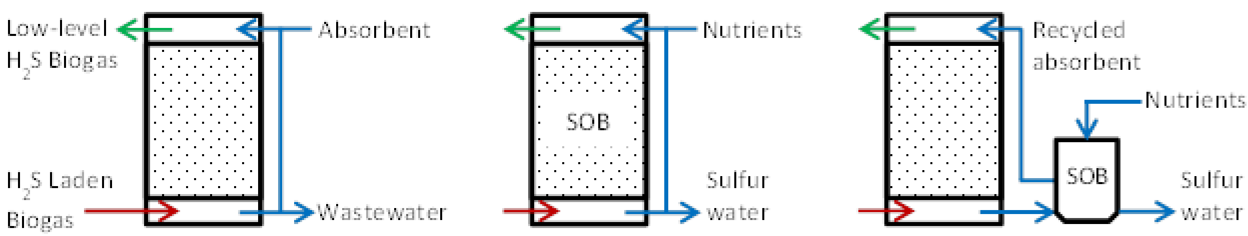
Oxygen (air) pumped limitedly into a digester headspace stimulates H_2S oxidation by SOB colonizing netting material or other media installed in the digester headspace. Elemental sulfur is formed and sloughs into the substrate being digested. This approach is effective and low-cost as it avoids the need for secondary treatment, but it must part of the original design as long biogas headspace residence times (> 5 h) are required. *This approach is used by some NYS operations and is worth considering when planning a new digester project.*

Biotrickling filters (BTF)

BTF are reactors typically packed with plastic media which provides large surface area for SOB colonization. A liquid trickling-phase is continuously cycled through the reactors like chemical scrubbers. Instead of being designed to only capture and flush H_2S, the liquid in a BTF also delivers nutrients to SOB that breakdown H_2S to sulfur and sulfate. BTFs are relatively low-cost, robust to operational changes, and other than backwashing media 2-4× per year, are relatively low-maintenance. *In NYS, BTFs are the most commonly used technology for H_2S removal from biogas, in-part because they can be retrofitted to existing digester systems* (*See Parts 3 & 4 of this Series for more on BTF*).

Bioscrubbers

Bioscrubbers use chemical scrubber towers to absorb H_2S, then a separate bioreactor with immobilize SOB to oxidize the H_2S. While this two-stage configuration can improve system control, it has higher costs than BTF systems where H_2S capture and breakdown are integrated. *While theses system are not used on farms for biogas clean-up, the separation of capture and treatment systems may offer some advantages such as easier maintenance and reduced tower cleaning.*



Simplified schematics of a chemical scrubber (left), biotrickling filter (center), and bioscrubber (right).

FACT SHEET SERIES

Hydrogen Sulfide Removal from Biogas

Part 1: Available technologies for hydrogen sulfide removal from biogas
Part 2: Microbial underpinnings of H_2S biological filtration.
Part 3: Biotrickling filters for H_2S - Overview of configuration and design.
Part 4: Biotrickling filters for H_2S – Improvement opportunities

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REFERENCE

Muñoz, R., Meier, L., Diaz, I. & Jeison, D. (2015) A review of the state-of-the-art of physical/chemical and biological technologies for biogas upgrading. *Rev. Environ. Sci. Biotechnol.*14:727-759.