BIOGAS UPGRADING - DESULFURIZATION
Part 1: What are the available technologies for biogas desulfurization?

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Biogas, a methane (CH_4) rich gas produced from anaerobic digestion of organics, is a valuable renewable fuel. Upgrading biogas, the process of removing impurities and concentrating CH_4, produces a cleaner, more useful/valuable fuel. While biogas can be upgraded to biomethane (>95% CH_4, see footnote), a fuel that can be injected into natural gas grids or used in vehicles, this level of upgrading is cost prohibitive for most farms. More typical on-farm use of biogas is in boilers and engine-generator sets, where lower CH_4 levels (>50%) can be used providing water and hydrogen sulfide (H_2S) are removed. Combinations of demisters, condensation sumps, and chillers are used for dewatering. Many developed technologies remove H_2S (desulfurization), and are highlighted below.

PHYSICAL/CHEMICAL REMOVAL

Several physical/chemical approaches based on chemical engineering unit operations are available for biogas desulfurization.

In-situ H_2S precipitation

Soluble iron salts (e.g. $FeCl_2$, $FeSO_4$) added to digester influent reacts with H_2S to form insoluble iron sulfide. This approach is most useful at high H_2S concentrations. *Total H_2S reduction is typically not cost-effective due to iron salt loading costs, but some farms in the northeast do utilize the technology.*

H_2S adsorption (Iron sponge)

Other iron salts (e.g. Fe_2O_3, $Fe(OH)_3$) immobilized on woodchips 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 -12 times by aeration (~33% of the adsorption capacity is lost during each regeneration). Regeneration is also very exothermic and can result in woodchip auto-ignition, but is usually controlled by adding moisture. The total annualized capital and operating cost of an iron sponge for a 125 cfm biogas flowrate is estimated at $36,500. The required media replacement frequency and cost have led most operators of large-scale anaerobic digesters to select other technologies for primary treatment. *Although few NYS farms use an iron sponge for primary treatment, iron sponges are quite suitable for secondary polishing and as a backup during the downtime of other desulfurizing systems.*

Membrane separation

Membranes made of selective materials (e.g. polymeric polyetheretherketone) that allow H_2S to permeate but retain CH_4 can be used to concentrate and desulfurize biogas at high efficiencies. *The high cost and fouling issues associated with this technology have limited its use for biogas systems on dairy farms.*

H_2S absorption (Chemical Scrubber)

Water, water with chemical reagents (e.g. Fe_2O_3, NaOH, Fe^{3+}/EDTA) 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. Depending on the liquid phase, sulfur recovery and absorbent regeneration is possible in auxiliary reactors. *H_2S 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 utilize H_2S as an electron donor and CO_2 as a carbon source, can be harnessed to desulfurize biogas (*see Part 2 of this Series*).

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 digester. This approach, best suited for long biogas headspace residence times (> 5 h), is effective and low-cost (if part of the design) as secondary treatment in not needed. *This approach is used by some NYS operations and is worth considering when planning a new digester project.*

Biofilters

Biofilters are reactors packed with organic media which provides nutrients and support for naturally occurring SOB. Biogas and air, forced through the media at short residence (~1 min.) enable H_2S oxidation. Though low-cost, targeting only H_2S removal is difficult due to complex microbial interactions. *As a result, biofilters are better suited to mitigate odorous, mechanically ventilated farm emissions.*

Biotrickling filters (BTF)

BTFs are similar to biofilters, but use plastic media, and are similar to scrubbers, but the continuously cycled trickling-phase not only helps capture H_2S, but delivers H_2S and nutrients to SOB on the media, and flushes the breakdown products elemental sulfur and sulfate. BTFs are relatively low-cost, robust to operational changes, and other than periodic media cleaning are low-maintenance. *In NYS, BTFs are the most common form of biogas desulfurization, somewhat because they can be retrofitted to existing digester systems* (*See Parts 3 & 4 of this Series*).

Bioscrubbers

Bioscrubbers use a chemical scrubber tower to absorb H_2S, then a separate bioreactor with immobilize SOB to oxidize the H_2S. While this two-stage configuration improves system control, the packed bed tower of a BTF system offers higher surface area for H_2S capture and the requirement of two reactors increases costs. *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 reduced tower cleaning frequency.*

FACT SHEET SERIES

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REFERENCE

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