BIOGAS UPGRADING - DESULFURIZATION
Part 2: Microbial underpinnings of H_2S biological filtration.

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BIOLOGICAL UTILIZATION OF H_2S

Sulfur oxidizing bacteria (SOB) are lithoautotrophs; *lithos* meaning rock or mineral, for their ability to feed on elemental sulfur (S^0); *autotroph* meaning self-feeding, for their ability to produce the complex compounds needed for cell growth - carbohydrates, proteins, fats, nucleic acids - from simple substances - energy from hydrogen sulfide (H_2S) and oxygen (O_2), and carbon from carbon dioxide (CO_2). The biological oxidation of H_2S can be described by reactions 1 - 4 (Muñoz et al. 2015).

$H_2S \leftrightarrow H^+ + HS^-$ (non-biological) (1)

$HS^- + 0.5\ O_2 \rightarrow S^0 + OH^-$ (biological) (2)

$HS^- + 2\ O_2 \rightarrow SO_4^{2-} + H^+$ (biological) (3)

$SO_4^{2-} + H_2O \rightarrow H_2SO_3 + O_2$ (non-biological) (4)

When O_2 from air is not limiting (aerobic conditions, 3), sulfate (SO_4) is preferentially produced. When O_2 is limiting, S^0 is preferentially produced (2). When O_2 is depleted (anaerobic conditions), SOBs use nitrate (NO_3) in place of O_2 (5 & 6).

$3H_2S + NO_3^- \rightarrow 3S^0 + 0.5N_2 + 3H_2O$ (biological) (5)

$3H_2S + 4NO_3^- \rightarrow 3SO_4^{2-} + 2N_2 + 6H^+$ (biological) (6)

As O_2 in air, unlike NO3-salts, is freely available, anaerobic desulfurization is not typically used for biogas upgrading. However, successfully upgrading biogas using aerobic desulfurization, requires a balance between diluting biogas with air, and providing enough O_2 to form SO_4 (which can be flushed from a biotrickling filter(BTF)) and not S^0 (which forms caking deposits in a BTF) (Muñoz et al. 2015).

OPTIMAL SOB GROWTH CONDITIONS

SOBs belong to the genera *Acidithiobacillus*, *Halothiobacillus*, *Paracoccuc*, *Sulfurimonas*, *Thiobacillus*, and *Thiomonas*. The optimal growth temperatures for these bacteria are 82-95°F. Most SOBs have optimal activities at pH 6-8. *Thiobacillus* spp. typically dominate at neutral pH. Some SOBs show high activities at pH 2-4 and can tolerate acidic conditions < pH 2. BTFs operated under acid conditions are typically dominated by *Acidithiobacillus* spp. such as *A. thiooxidans* (Figure 1) (Montebello et al., 2013).

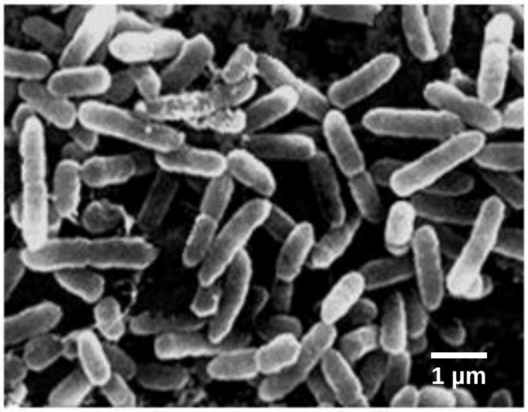

Figure 1 Scanning electron micrograph of *A. thiooxidans* (Khan et al., 2012)

BIOFILMS

SOB bacteria are able to form complex aggregations of cells and extracellular metabolites on the surfaces of bioreactor media. These *biofilms* help protect SOBs from acidic conditions while providing enhanced surface area for desulfurization. Excessive biofilm growth can clog desulfurization systems (Figure 2).

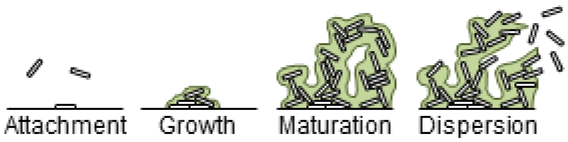

Figure 2 Simplified biofilm growth cycle.

SOB INOCULATIONS & MICROBIAL COMMUNITY INTERACTIONS

Though ubiquitous in the environment and attachment or 'seeding' can occur naturally from aerosolized cells present in the biogas, biological desulfurization systems are typically inoculated with SOBs to reduce start-up time. Systems can be inoculated with manure, activated sludge, or with specially developed bacterial cultures. As desulfurization systems are unique and non-sterile, microbial community shifts typically occur that deviate from the inoculum. This is dictated by both system operating conditions and microbial interactions. *Some farms collect the liquid trickling-phase from BTFs (which is enriched in the system's unique SOB community) prior to cleaning media, and use this to re-seed the system after cleaning.*

In counter-flow BTFs, most H_2S elimination occurs in the lower portion of the reactor where biogas and O_2 are loaded. SO_4 is also preferentially produced here due to high O_2 supply, while S^0 formation is more prevalent in the upper portions of the system. In BTFs where flow is co-current, most H_2S elimination occurs in the upper portion of the reactor with S^0 formation more prevalent in the lower portions of the system. Microbial communities are recognized to patrician in biogas desulfurization systems along these concentration gradients (Montebello al., 2014).

Research is needed to better understand microbial interactions in bio desulfurization systems and their responses to operational conditions. This knowledge could help optimize inoculations to speed the establishment of an active and robust desulfurization microbial consortium, and optimize operational parameters so O_2 doesn't become limiting as H_2S concentrations fluctuate or SOB biofilms and S^0 deposits thicken.

FACT SHEET SERIES
Biogas upgrading - Desulfurization

Part 1: What are the available technologies for desulfurization of biogas?
Part 2: Microbial underpinnings of H2S biological filtration.
Part 3: Biotrickling filters for H_2S - Overview of configuration and design.
Part 4: Biotrickling filters for H_2S - Process control options.

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