Biogas Upgrading – Desulfurization

Part 5: In-situ H_2S removal – biological desulfurization

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Overview

Biological desulfurization can occur when a small, continuous, and regulated supply of oxygen (O_2) is introduced in the anaerobic digester (AD) headspace. Sulfur oxidizing bacteria (SOB) feed on hydrogen sulfide (H_2S), reducing the concentration of H_2S in biogas.

Although simple and highly effective, this method results in a dilution of the biogas methane concentration since ambient air (78% nitrogen and 21% O_2) is normally used to supply the O_2 needed by the SOB. In the case where biogas is going to be further processed into renewable natural gas (RNG), the dilution air, especially residual O_2, needs to be removed to meet most pipeline gas quality specifications.

The biological breakdown of H_2S by SOB occurs in a sequence of four reactions. The first and second reaction results in the precipitation of elemental sulfur (S^0), while the third and fourth reaction form sulfurous acid (H_2SO_3), a weak acid. Both sets of reactions reduce the H_2S in the biogas.

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

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

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

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

Micro-aeration in AD headspace

A regulated amount of O_2 between 0.3% and 3% (typically 1%) of the AD biogas production flow rate is injected into the headspace of an AD to create a micro-aerobic environment, most commonly using ambient air (Figure 1). The airflow rate needed to convert H_2S to elemental sulfur (equation 1 and 2) varies based on both the sulfur concentration in the feedstock and the biogas production rate. Airflow rate should be controlled to match the varying H_2S concentrations. A handheld gas analyzer or sample tubes can monitor H_2S regularly to inform the airflow into the AD headspace. Maintaining residual O_2 levels at 0.3% to 0.5% of biogas (volume/volume) will keep H_2S concentration between 100 and 500 ppm_v. [1]

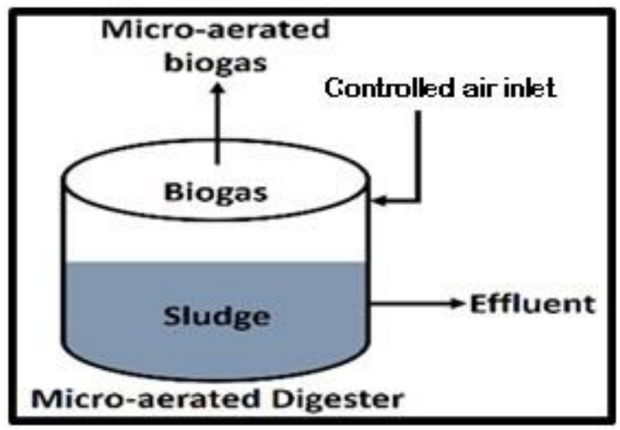

Figure 1. A basic representation of in-situ air injection.

Safety and practical considerations

Overdosing of air into an anaerobic digester can be a significant safety issue if not carefully controlled. An explosive mixture of the gases can occur in the range of 6% to 12% O_2 when the methane (CH_4) concentration in the biogas is 60% or higher. [2] An air metering pump can regulate the air flow to not exceed a set percentage of the biogas volume. If the airflow control stops working, there is potential for an explosive mixture to occur. Air injection systems should be closely monitored to mitigate this safety concern as well as to maintain biogas quality. Controlling micro-aeration rates to continuously maintain an O_2 concentration of 0.4% can minimize residual O_2 while achieving effective H_2S removal.

As previously mentioned, the dilution of biogas with the inert form of nitrogen in the air injection and residual O_2 needs to be considered for RNG applications. Studies show that when the O_2 concentration is less than or equal to 1%, there is no apparent effect on the methane (CH_4) production rate. This is likely because methanogens are present in the AD substrate and not exposed to the O_2 in the headspace.[3]

The micro-aerobic environment can cause elemental sulfur to accumulate on the digester walls and cover where the SOB grow (Figure 2). H_2S removal efficiency may decrease if too much sulfur builds up due to decreased biogas residence time and O_2 transfer rates.[4] Sulfur build-up can be avoided by using netting or a wooden structure inside an AD with a dome cover to provide the surface area needed for the SOB activity. The elemental sulfur and sulfurous acid drop off the netting and are removed with the digestate.

Figure 2. Accumulation of elemental sulfur on the digester walls and cover when netting is not used.[5]

FACT SHEET SERIES: Biogas Upgrading – Desulfurization

Part 1: What are the available technologies for biogas desulfurization?
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[2] Wellinger, A., and Lindberg A. 2000. "Biogas upgrading and utilization." IEA Bioenergy. Task 24.
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