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Hydrogen Sulfide (H_2S) Removal at a Northeastern Dairy Farm Digester using Micro-aeration: Case Study

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Contents:

Figure 1. Micro-aeration Pump

Hydrogen Sulfide Scrubber Overview

H_2S scrubber type	Micro-aeration
Year commissioned	2011
Number of cows	650
Biogas utilization	140 kW engine generator

Farm Description

- The farm milks ~ 650 cows
- The digester was commissioned in 2008, and the air pump for H_2S scrubbing was added in 2011.

Reason for Scrubber Installation

Prior to installing an air pump for in-situ biological scrubber, the farm had a biotrickling filter (BTF) scrubber. A BTF scrubber has packing media for the growth of sulfur oxidizing bacteria through which the nutrient water ‘trickles’ countercurrent to biogas flow. The nutrient water supports the growth of sulfur oxidizing bacteria (SOB). The BTF unit that was installed at the farm never worked properly. As the farmers had invested ~$30,000 into the BTF scrubber, it was decided to look into in in-situ biological scrubber, consisting of micro-aeration into the digestion vessel, as a low-cost option to help decrease H_2S levels in the biogas.

Scrubber system

System description

The scrubber system has one component: an air pump that pumps air into the headspace of the digester.

Pump:

The pump (model SST10 from Aquatic Ecosystems Inc.) is a 1 phase pump, rated at 0.3 hp, 30 cfm, and 115V / 230V. The air pump was set to inject air at a consistent rate of 1.8 scfm. A rotameter attached to the air pump was used to measure the flowrate.

Process description

Air is pumped into the headspace of the digester at a constant flowrate of 1.8 scfm. The injection of a small amount of air into the digester headspace creates a micro-aerobic environment. Biological conversion occurs within this micro-aerobic environment, as sulfur oxidizing bacteria (SOB) already present in the digester, use H_2S as their primary energy source. The SOB oxidize H_2S to elemental sulfur at the interface between the biogas headspace and the liquid manure.

The produced elemental sulfur can build up on the walls of the digester and may need to be removed periodically to remove crusting at the air-water surface, which can inhibit the access of H_2S and oxygen to the SOB. To remove the sulfur build-up from the digester headspace, the cover would need to be removed.

Scrubber Performance

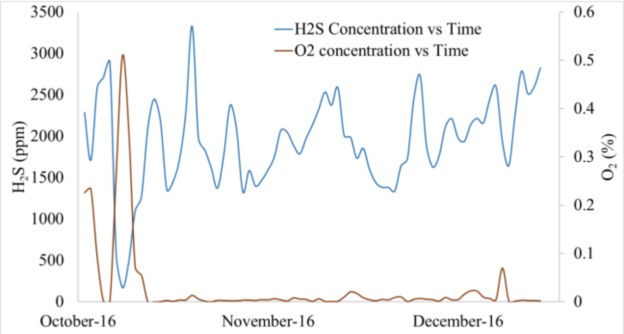

Figure 2: Hourly biogas hydrogen sulfide (H_2S) and oxygen (O_2) concentrations in the biogas when air was pumped into the digester headspace.

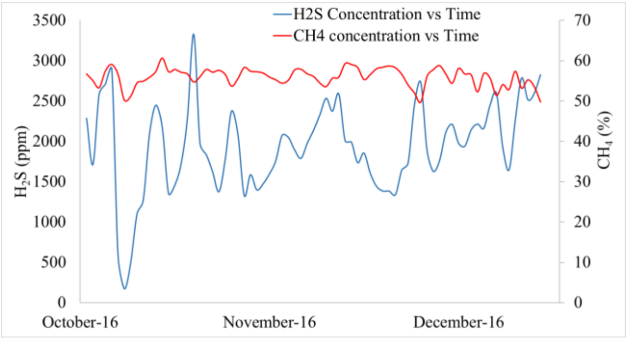

Figure 3: Hourly biogas hydrogen sulfide (H_2S) and methane (CH_4) concentrations when air was pumped into the digester headspace.

Performance Summary:

Average H_2S concentration (ppm)	1938 ± 23
Average O_2 concentration (%)	0.030 ± 0.004
Average CH_4 concentration (%)	56.2 ± 0.1%
Engine-Generator Capacity Factor	0.76

With micro-aeration, it is not possible to measure H_2S concentrations in the produced biogas before scrubbing. Therefore, only the concentrations after desulfurization can be reported, which does not allow for H_2S removal efficiency to be calculated.

The results from the study showed that the average H_2S concentration during the monitoring period of October to December 2016 was 1938 ± 23 ppm, with an oxygen (O_2) concentration of 0.030 ± 0.004%. The H_2S concentrations varied from a high of 3300 ppm to less than 100 ppm. This large variability in H_2S could be due to inconsistent treatment with the micro-aeration system, which could be attributed to clogging of the air pump, insufficient air quantity injected with increasing biogas production, and/or variability in the feedstock sulfur concentrations. During the study period, the average methane (CH_4) concentration was 56.2 ± 0.1% with fluctuations between 50% - 60% CH_4 in the biogas. On October 15th, the H_2S concentration decreased below 100 ppm (0.01%), while the O_2 concentration rose to 0.5%, and the CH_4 concentration dropped to 50%, likely due to an increased level of nitrogen (N_2) being introduced into the biogas stream with a micro-aeration rate that did not match the biogas production rate.

After the continuous sampling period, additional tests showed that on February 4th, 2017, the H_2S concentration was 1800 ppm, with 0% O_2 and N_2 concentration. The 0% O_2 and N_2 indicated that the airflow pump was not injecting air into the digester due to possible clogging of the inlet air tube, resulting in a higher H_2S concentration in the biogas. It is likely the farmer had stopped cleaning out the airflow line after the study period. He was advised to unclog the airline to allow air to be injected into the digestion headspace to reduce H_2S concentration in the biogas coming out of the digester. The biogas was tested again on June 9th, 2017, and the H_2S concentrations was 3233 ppm. The farmers had informed us that the feedstock was changed from solid food waste to liquid food waste recently, which could have increased the H_2S concentration. The biogas had a 0% O_2 with a 0.7% balance (N_2), which indicated that the micro-aeration system was functioning, but the oxygen was being utilized completely. It is possible that due to the higher biogas production and higher sulfur levels with the change in feedstock, the micro-aeration rate was inadequate to desulfurize the biogas sufficiently.

Economics

Capital Costs

The total capital cost of the scrubber system was approximately $450 for the air pump.

Table 1: Component annual capital cost

Component	Purchase Cost	Useful life (yrs)	Salvage Value[1]	Annual Cost[2]
Air Pump	$450	5	$45	$95

[1] Salvage value was assumed to be 10% of the purchase cost

[2] Lost opportunity cost was assumed to be 5%

Installation and maintenance of the air pump was conducted by the farmer. Built-up sulfur in the digester had not been monitored/observed or cleaned out since the air pump was installed in 2011.

The total annual cost to own and operate the scrubber was $95.

Digester Operation and Maintenance Costs

Labor

This scrubber requires low maintenance due to its simplicity. The only maintenance for the air injector was cleaning out the air injector weekly, which was estimated to take 15 minutes per week and cost $120/year in labor costs (~$10/week).

Generator Maintenance

Table 2: Monthly generator maintenance costs

Month	Year	
July	2016	$ 1,190.00
August	2016	$ 1,190.00
September	2016	$ 3,355.95
October	2016	$ 1,190.00
November	2016	$ 1,400.00
December	2016	$ 1,400.00
January	2017	$ 1,400.00
February	2017	$ 1,400.00
March	2017	$ 1,795.00
April	2017	$ 10,797.50*
May	2017	$ 1,795.00
June	2017	$ 1,795.00
	Yearly Total	$ 28,708.45

***Engine Head Repair**

The farmer's total annual cost to own and operate the scrubber was around $120. However, maintenance costs and repairs to the engine-generator (including oil change) cost $28,708 from July 2016 to June 2017 (one year).

Lessons Learned

H_2S concentrations varied from a high of 3300 ppm to less than 100 ppm. The high H_2S concentration in the biogas was likely due to inconsistent treatment with the micro-aeration system, possibly due to clogging of the air line from the pump to the digester, insufficient micro-aeration rate, or variability in the feedstock sulfur concentrations. Changes to feedstock inputs likely changed sulfur concentrations in the feedstock of the digester. There were also likely changes in biogas production with the new feedstock, but the installed air pump did not have an automatic air flow regulator to change the airflow according to the amount of H_2S in the biogas. Without a regulator, changes to the air flow rate should have been adjusted manually. However, during the study period, the air flow rate remained constant and was not changed as sulfur concentrations fluctuated. The large fluctuations in the H_2S concentrations were likely due to an insufficient amount of oxygen for when in H_2S concentration in the biogas spiked.

The results showed that it is important to monitor biogas quality for H_2S, O_2, and N_2 concentrations. When H_2S concentration is high, O_2 is at 0%, a higher micro-aeration rate is needed to decrease H_2S concentrations. The presence of N_2 shows that air was being injected into the digester. However, the O_2 was completely utilized, and a higher air flow rate was needed for adequate H_2S removal. Keeping O_2 levels greater than 0.5%, but below 1.0% is an ideal level for adequate H_2S removal. Not only is monitoring biogas quality important for keeping H_2S levels low, it can help identify when the system is not operating properly. The drawback of adding excess air is the addition of N_2, which can dilute the biogas stream and lead to a lower CH_4 percentage.

Additionally, the micro-aeration pump at the farm did periodically clog. Clogs in the micro-aeration pump can result in lower amounts of air injected into the digester, leading to lower treatment effects. The lack of treatment can go unnoticed without biogas monitoring to determine when changes in H_2S concentrations are occurring. The clog was first noticed when the biogas concentration was measured and both O_2 and N_2 levels were at 0%. This indicated that air was not being pumped into the digester.

Lastly, the biogas flow meter installed on farm was not functional for several years. The farmer noted that since the flow meter data was not required for electrical energy generation credits, costly maintenance of the biogas meter for repair and calibration was not a priority. Without biogas volume measurements, it difficult to calibrate the micro-aeration rate to the biogas production rates.

Through the study, it was determined that for a micro-aeration scrubber system to work properly monitoring biogas quality and adjusting airflow rate to match changes in H_2S concentrations is important for keeping the system running efficiently. It should also be noted that addition of excess air into the digester headspace could lead to dilution of the CH_4 in the biogas stream. Technical knowledge of H_2S removal through micro-aeration as well as monitoring and adjusting the air flow rate is critical to ensure efficient removal of H_2S when using micro-aeration.

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