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Hydrogen Sulphide Removal at Spruce Haven Farm, LLC: Case Study

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Figure 1. Spruce Haven Biological Trickling Filter

Hydrogen Sulphide Scrubber overview

H_2S scrubber type	Biological Trickling Filter
Scrubber designer	Larsen Engineering
Year commissioned	2014
Number of cows	1,850 cows, 1,750 heifers
Dimensions (height, diameter)	20ft, 7.5 ft.
Media volume	462 ft^3
Water use	
Vessel material	Fiberglass
Design temperature	100°F
Media	Plastic inserts
Biogas utilization	Guascor 502 kW combined heat and power
Monitoring results available	Yes

Farm overview

- Spruce Haven Farm, LLC, managed by Doug Young, is located in Cayuga County, New York.
- The farm herd has 3,360 Holsteins and milks ~1,500 cows.
- Digester construction began in Spring 2014, with the system operating by October 2014.
- See "Anaerobic Digestion at Spruce Haven Farm, LLC: Case Study" for more information: http://www.manuremanagement.cornell.edu/Pages/General_Docs/Case_Studies/Case_Study_Spruce_Haven_2016.pdf

Why the H_2S Scrubber?

The scrubber at Spruce Haven Farms, Inc. was included with the initial system design and was in place when the anaerobic digestion system was commissioned. The purpose of the scrubber is to remove Hydrogen Sulphide (H_2S) from the biogas stream to reduce the maintenance costs and prolong the lifespan of the engine-generator equipment. With the H_2S scrubber operational, oil changes for the 502 kW Guascor engine-generator occur every 900 hours of operation.

Scrubber system

System description

The scrubber system has several components (see Figure 2) including:

<u>Vessel</u>

The reaction vessel is 20 feet tall, and 7.5 feet in diameter. It's constructed out of fiberglass, with access holes at the top, side and bottom. The vessel is insulated with 2" of foam insulation. The interior volume of the reactor is approximately 770 ft^3.

<u>Media</u>

The media on which the biofilms form is a plastic honeycomb material, with a volume of 462 ft^3. The media requires a thorough cleaning twice per year, during which water is blasted in to dislodge accumulated elemental Sulfur. It is estimated that the media will require replacement every 4 years at a cost of $8,000.

<u>Air Injection</u>

Oxygen (from ambient air), is introduced into the biogas stream to a concentration of 2% (from trace concentrations in the raw biogas), through an air injection pump. The injection rate of air varies based on the measured biogas flowrate. Though the biogas is at a negative pressure at the inlet where air is introduced, air is introduced with a pump for more precise application rates.

<u>Water Distribution</u>

Water is constantly circulated through the plastic media by means of a 3 HP pump at a rate of 100 GPM. A single manifold at the top of the reactor distributes the water evenly over the media.

<u>Reservoir</u>

The base of the reactor vessel acts as a reservoir that collects the solution that trickles through the media. The pH of the system is measured and controlled through sensors located in the reservoir, and is typically 1.5. When the pH of the system drops due to accumulated Sulphuric Acid a flush is triggered to increase the pH.

<u>Nutrient system</u>

The microbes that fix the Sulfur require supplemental nutrients, which are pumped into the reservoir as necessary from a concentrated 275 gallon supply tote. The system uses approximately three totes of nutrient solution per year at a cost of $2,600 per tote.

<u>System Heat</u>

Hot water (190 F) to supply heat for the system is piped in a closed loop, from the waste heat reservoir of the engine generators in a 1" supply hose, after which it is distributed throughout the vessel in ½" pex.

<u>Demister</u>

The demister removes water droplets from the biogas stream. Condensed liquid drains back into the main vessel.

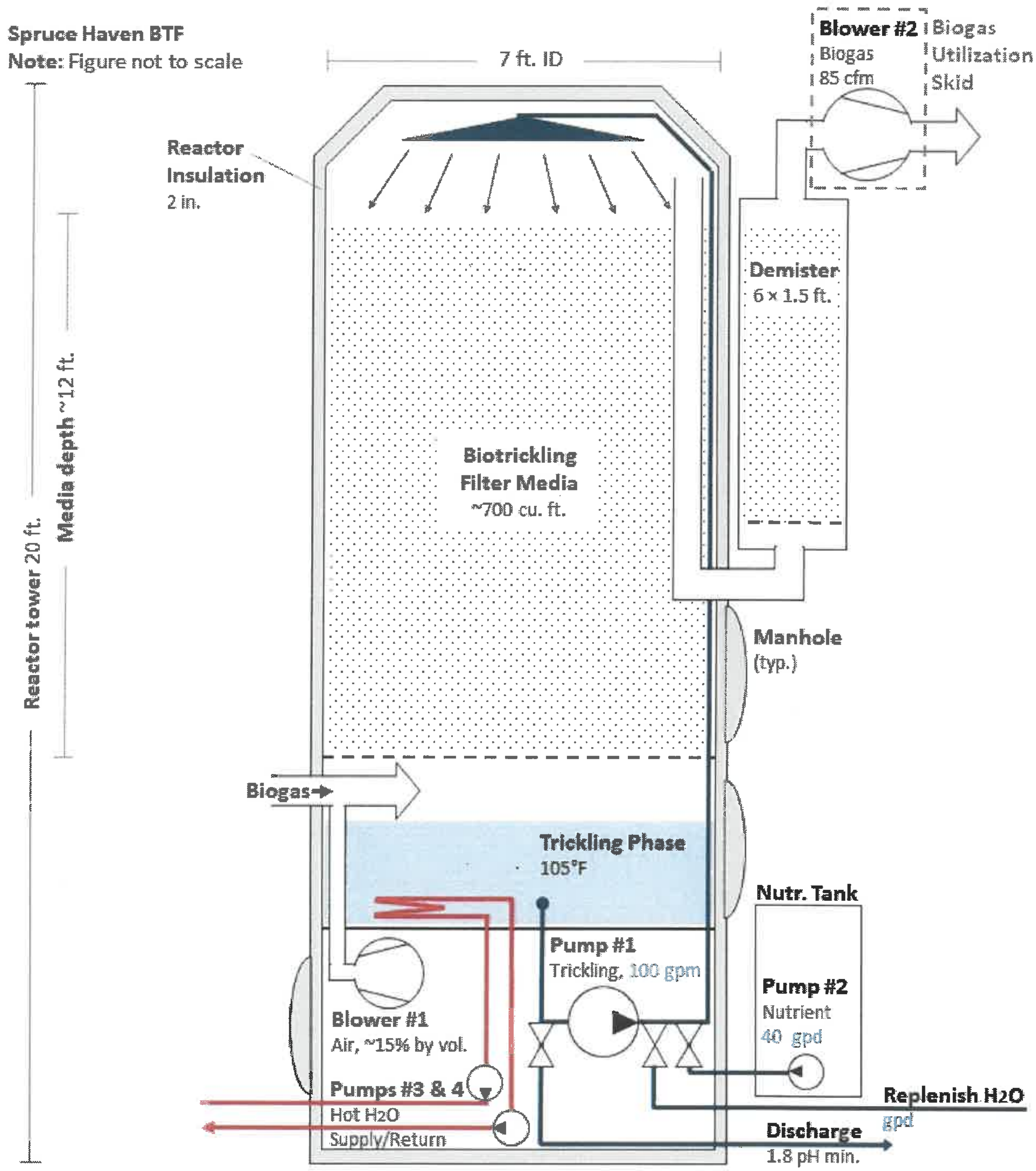

Figure 2. System Diagram of Spruce Haven Biological Treatment System

Process description
For a more in depth description of the Biological Trickling Filter process please refer to the biogas cleanup Fact sheet series, available on the Dairy Environmental Systems website (future link).

Biogas is drawn into the scrubber vessel at the base, and flows upward through the column of media. The biogas blower placed on the outlet of the reactor vessel creates a vacuum of 0.7-0.8 in. WC within the unit. Within the column, Sulphur oxidizing bacteria metabolize the H_2S in the biogas and convert it to Sulfate, and elemental Sulphur. After leaving the reactor, the biogas flows through a demister to remove water droplets from the biogas.

The elemental Sulfur builds up on the media, which must be cleaned several times per year (and/or replaced when the buildup is such that effective cleanup isn't practical). Sulfate is water soluble and dissolves in the tricking water, which transports it to the sump. The Sulfate forms Sulfuric acid which triggers a flush of the system when the pH drops below a target of 1.5. Approximately ????? gallons of fresh water are used per day to flush out the system. Flushed water is piped to the main digester effluent storage ponds for eventual field distribution.

Scrubber Performance
The concentrations of H2S were measured with a Siemens Ultramat 23 Biogas Analyzer equipped with a multiplexer which allowed the system to switch sampling between the inlet (pre BTF) and the outlet of the BTF (post BTF) measured results are shown in Figure 3.

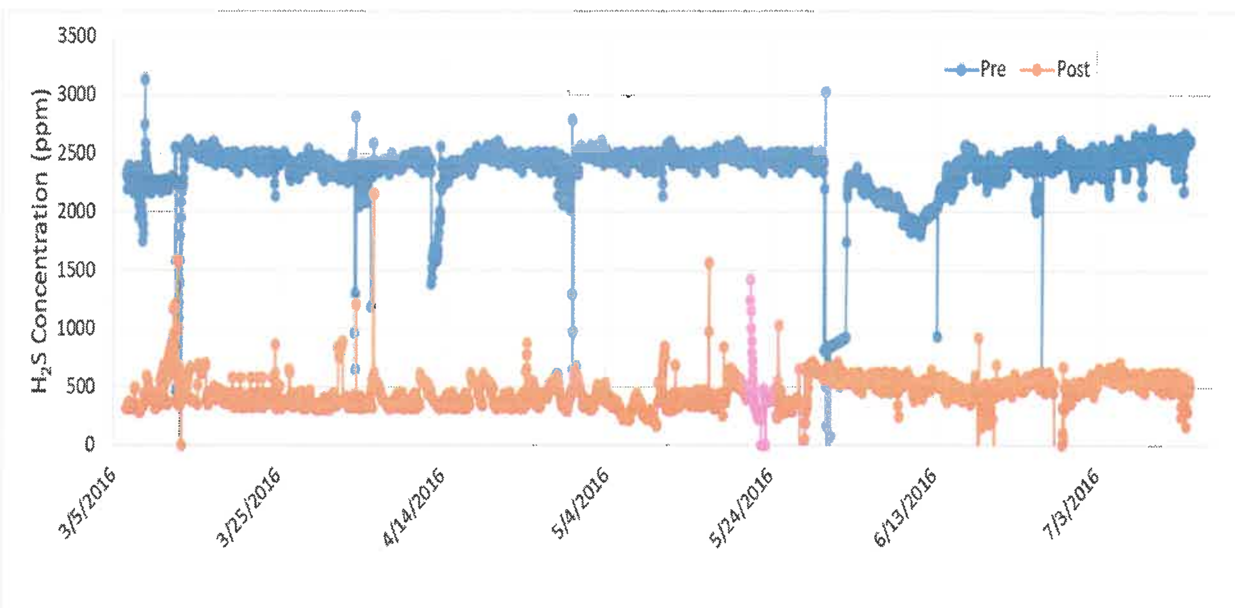

Figure 3: Spruce Haven Biogas H_2S concentrations before and after the BTF

Performance Summary:

Average Pre BTF H_2S Concentration (ppm)	2,350 +/- 315
Average Post BTF H_2S Concentration (ppm)	450 +/- 190
Average H_2S Removal Efficiency (%)	80.1
Average H_2S removed per hour (lbs/hr)	0.78
Engine-Generator Capacity Factor	0.68

Over the course of the monitoring period illustrated in Figure 3, the concentration of H_2S in the raw (untreated) biogas averaged 2,350 ppm with a standard deviation of 315 ppm. This is a fairly typical value on the low side when compared to other local anaerobic digestion systems.

Post treatment concentrations averaged 450 ppm with a standard deviation of 190 ppm. This average is higher than other BTF systems we have examined, but still below the target threshold target for engine-generator operation. Overall system H_2S removal efficiency was calculated to be 80.1% over the course of the monitoring period.

Part of the reason for the lower overall system removal efficiency was due to issues with the supply of biogas due to complications with the cover of the Anaerobic Digester, and operation of the digester in general (the farm uses sand bedding, and the sand/manure separator operational issues complicate digester operation). The capacity factor of 0.68 indicates that the system was not operating near peak electricity production potential.

Economics

Capital Costs

The total capital cost of the Scrubber system was approximately $184,500 broken down as follows:

- Reactor vessel $94,900
- Construction/installation of the BTF system (foundation and system installation): $51,000.
- Trickle Media, $8,000
- Gas Analyzer, $22,000
- Pumps, plumbing and blowers, $8,600

The capital costs have been annualized (Table 2) to illustrate the yearly capital cost of the BTF ($25,564).

Table 1: Component Annual capital cost

Component	Purchase Cost	Installation Cost[1]	Useful life (yrs)	Salvage Value	Annual Supplies	Annual Cost[2]
Scrubber Foundation	$0	$11,000.00	20	$0		$275
Reactor Vessel	$94,900.00	$40,000.00	10	$949		$16,151
Trickle Media	$8,000.00	$0.00	4	$0		$2,200
Air Injection (Blower #1)	$2,000.00	$0.00	5	$200		$415
Biogas Blower (Blower #2)	$2,500.00	$0.00	5	$250		$519
Circulation Pump (Pump #1)	$3,200.00	$0.00	5	$320		$664
Nutrient Pump (Pump #2)	$200.00	$0.00	5	$0		$45
Hot Water Supply pumps (Pump #3 and 4)	$700.00	$0.00	5	$70		$145
Gas Analyzer	$22,000.00	$0.00	5	$0	$750	$5,150

[1] If there is no value for installation cost it is assumed to be a part of the Reactor Vessel installation cost

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

Operation and Maintenance Costs
Scrubber performance and operation and maintenance costs were monitored over the course of 18 months (2016 to 2017).

Labor
Over the course of a year, approximately 78 hours was spent maintaining the scrubber equipment, for an annual cost of $3,120. In addition to regular maintenance and repairs, an additional $1,200 per year was spent on cleaning out the reactor vessel (2 cleanouts per year taking approximate 16 hours of labor).

Nutrient Solution
Three totes of nutrient solution were used per year, at a cost of $2,600 per tote (~$9.50 per gallon) for an annual cost of $7,800.

Replacement Parts/Supplies
Parts and supplies for use in maintaining the equipment totaled $1,600 per year.

Utilities
Over the course of a year the biogas scrubber used approximately 11,000 kWh of electricity, and 85 MMBtus of hot water. The hot water was provided from the heat recovered from the engine-generator set (from the hot water reservoir), and distributed to the scrubber through a closed glycol/water loop.

The yearly operation and maintenance costs were $21,523.

The total annual cost to own and operate the scrubber is $39,304.

Lessons Learned

Originally a Landtec GA 3000 gas analyzer was used to monitor the post treatment concentrations of CO_2, CH_4, H_2S, and O_2 in the biogas (monitoring and reporting system performance was a requirement of NYSERDA who partially supported the purchase of the AD system.) Though not actually used for control of the BTF process, this data is useful for monitoring the performance of the filter, and to detect when the system may require a cleanout. Unfortunately the H_2S sensors have proven quite problematic in that they have routinely failed well before their expected lifespan of one-year. At approximately $800 each they represent a significant annual cost. Other biogas monitoring equipment such as Siemens also suffer from this issue (to the point where Siemens is no longer offering "high range" (0 to 5,000 ppm) H_2S sensing capability. The original Landtec GA 3000 has since been replaced with a Union Instruments (model INCA 4003) gas monitoring system, which monitors and records concentrations of CO_2, CH_4, H_2S, and O_2 in the biogas, both before and after the BTF.

The operation of the anaerobic digester itself has proven challenging for a number of reasons, which has translated into engine-generator down-time (no biogas flow) which in turn has affected the performance of the BTF. Unlike the digester, the volume of the reactor is primarily air, and so there is much less thermal mass to help maintain temperature during periods when heat is no longer being supplied.

Spruce Haven uses a sand-bedding system which poses additional maintenance and operational challenges for the digester system. Being a relatively smaller system, it is also more difficult to dedicate staff full time to system operation, and the time that is dedicated is usually spent maintaining the sand-separators.

The BTF has been in operation since commissioning of the digester and so a comparison of the oil-change frequency with and without a scrubber system is not possible. Assuming that the frequency of oil change would be 500 hours vs the current 900 hours with the BTF, the annual savings on oil changes would be $5,500. However a major consideration in including the BTF in the AD system is to delay the need to rebuild the engine-generator, which is estimated to cost $80,000. Added benefits include a significant reduction in Sulphur emissions from the engine-generator (SOX) and increased Sulphur recovery for use in crop fertilization (through field distribution of the recovered and stored BTF flush water).

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