Dairy Environmental Systems Program

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Hydrogen Sulphide Removal at Sunnyside Farms, Inc.: Case Study

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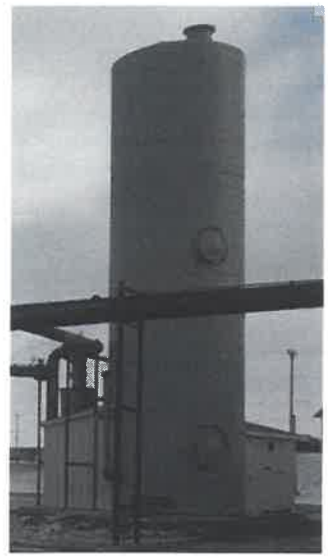

Figure 1. Sunnyside Biological Trickling Filter

Hydrogen Sulphide Scrubber overview

H_2S scrubber type	Biological Trickling Filter
Scrubber designer	American Biogas Conditioning, LLC (no longer in business)
Year commissioned	2015
Number of cows	4,200 cows
Dimensions (height, diameter)	42 ft, 11.5 ft.
Media volume	2,851 ft^3
Water use	2,500 gallons per day
Vessel material	Fiberglass
Design temperature	90°F
Biogas utilization	2, Guascor 500 kW engine-generators (total 1 MW)
Monitoring results available	Yes

Farm overview

- Sunnyside Farms, Inc, managed by Neil and Greg Rejman, is located in Scipio Center, New York.
- The farm milks ~4,200 cows.
- Digester was commissioned in May 2009.
- See "Anaerobic Digestion at Sunnyside Farms, Inc: Case Study" for more information:

http://www.manuremanagement.cornell.edu/Pages/General_Docs/Case_Studies/SunnySide_case_study.pdf

Why the H_2S Scrubber?

A new scrubber at Sunnyside Farms was retrofitted into the existing biogas handling system, to reduce biogas H_2S concentrations with the overall goal to lower the operation and maintenance costs of the farms two, 500 kW Guascor engine-generator sets. Before the scrubber was installed the oil in the engine-generator sets was changed every 750 hours of operation. With the scrubber, that frequency has dropped to every 1,200 and 1,400 hours (one engine-generator was installed in 2009, and the other in 2012). The current scrubber is actually the third scrubber system to be installed on farm, with the previous two systems failing to work effectively long term (with one system not working at all).

Scrubber system

System description

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

Vessel

The reaction vessel is 42 feet tall, and 11.5 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 4,000 ft^3.

Media

The media on which the biofilms form is a plastic honeycomb material available commercially. The media requires a thorough cleaning twice per year, during which water is blasted in to dislodge accumulated elemental Sulfur and biomaterial. It is estimated that the media will require replacement every 4 years at a cost of $13,000.

Air Injection

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.

Water Distribution

Water is constantly circulated through the plastic media by means of a 10 HP pump at a rate of 100 GPM. The vessel is divided into an upper and lower stage, with a separate trickling system installed at the top of each stage.

Reservoir

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.

Nutrient System

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 $1,100 per tote.

System Heat

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 1.5" supply hose, after which it is distributed throughout the vessel in ½" pex.

Demister

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

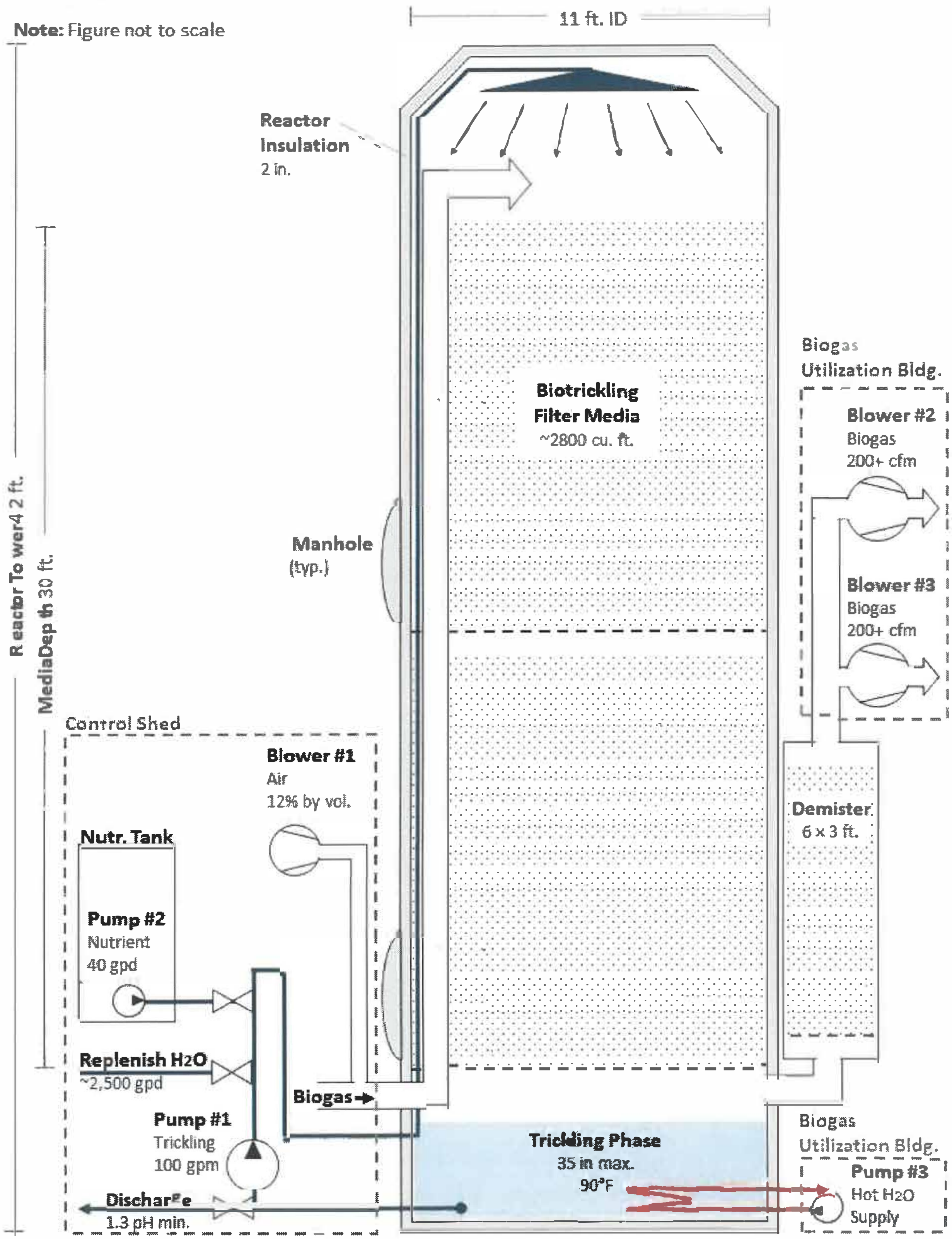

Figure 2. System Diagram of Sunnyside Biological Treatment System

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 an internal pipe to the top of the vessel. 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 at the base, the biogas flows through a demister to remove larger drops of water.

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 1.3, or every two hours (lasting 5 minutes for the upper and 10 minutes for the lower stages). Approximately 2,500 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 H_2S 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.

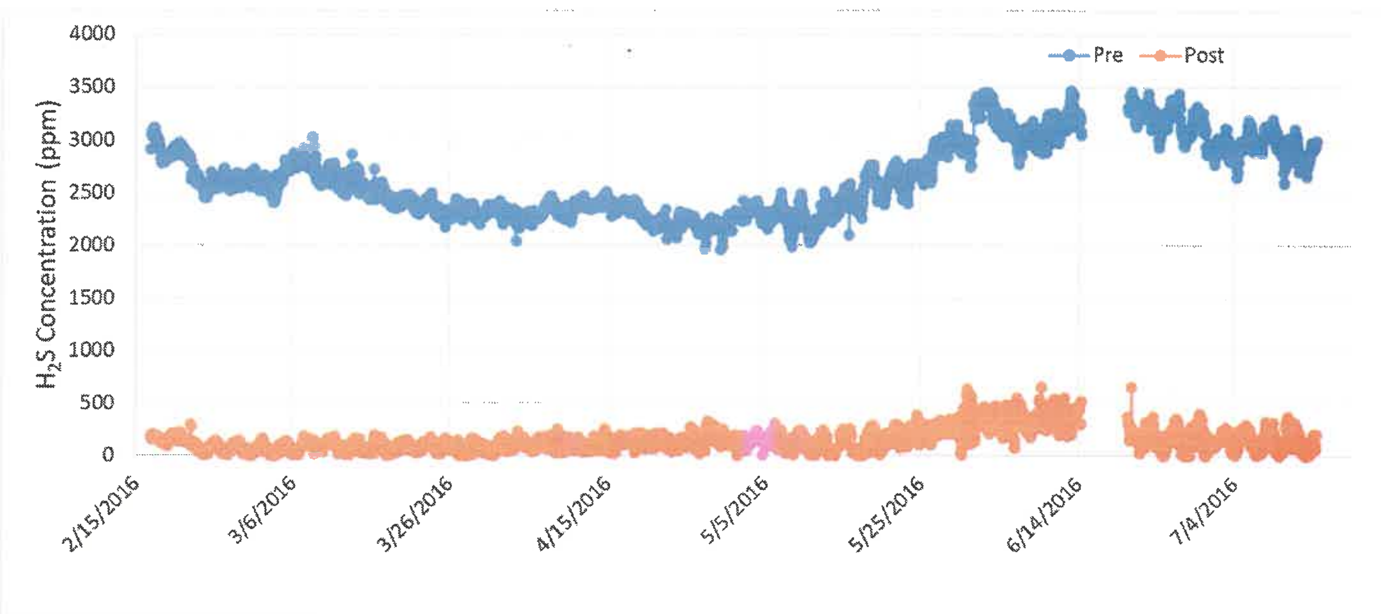

Figure 3. Sunnyside biogas H_2S concentrations pre and post BTF

Table 1. BTF Performance Summary

Average Pre BTF H_2S Concentration (ppm)	2,640 +/- 350
Average Post BTF H_2S Concentration (ppm)	150 +/- 110
Average H_2S Removal Efficiency (%)	94.5
Average H_2S removed per hour (lbs/hr)	5.22
Engine-Generator Capacity Factor	0.93

Over the course of the monitoring period illustrated in Figure 3, the concentration of H_2S in the raw (untreated) biogas averaged 2,640 ppm with a standard deviation of 350 ppm. This is a fairly typical value on the low side when compared to other local anaerobic digestion systems.

Post treatment concentrations averaged 150 ppm with a standard deviation of 110 ppm. Increases in concentration in the treated biogas were observed following the frequent flush cycling as well as a gradual overall increase, leading to a system shutdown and cleanout.

Overall system H_2S removal efficiency was calculated to be 94.5% over the course of the monitoring period (February 15, 2016 to July 15, 2016).

Biogas flow through the BTF is maintained during engine maintenance due to their being two separate engine-generator sets. While one engine-generator is worked on, the other continues to operate and consume biogas.

Economics

Capital Costs

The total capital cost of the scrubber system was approximately $412,000 broken down as follows:

- Reactor vessel $242,900
- Shipping/construction/installation of the BTF system (foundation and system installation): $107,000.
- Trickle Media: $13,000
- Gas Analyzer: $25,000
- Pumps, plumbing and blowers: $25,000

The capital costs have been annualized (Table 2) to illustrate the yearly capital cost of the BTF ($55,156).

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	$18,043	20	$0		$451
Reactor Vessel	$242,124	$88,853	10	$24,212		$39,556
Trickle Media	$13,000	$0	4	$0		$3,575
Air Injection (Blower #1)	$3,000	$0	5	$300		$623
Biogas Blower #2	$4,200	$200	5	$420		$917
Biogas Blower #3	$4,200	$200	5	$420		$917
Circulation Pump (Pump #1)	$11,500	$0	5	$1,150		$2,386
Nutrient Pump (Pump #2)	$200	$0	5	$0		$45
Hot Water Supply pump (Pump #3)	$1,500	$0	5	$150		$311
Gas Analyzer	$25,000	$0	5	$0	$750	$6,375

[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 156 hours was spent maintaining the scrubber equipment, for an annual cost of $5,772. In addition to regular maintenance and repairs, an additional $4,551 per year was spent on cleaning out the reactor vessel (2 cleanouts per year taking approximate 61 hours of labor per cleanout).

Nutrient Solution
Three totes of nutrient solution were used per year, at a cost of $1,100 per tote (~$4 per gallon) for an annual cost of $3,300.

Replacement Parts/Supplies
Parts and supplies for use in maintaining the equipment totaled $5,600 per year.

Utilities
Over the course of a year the biogas scrubber used approximately 45,000 kWh of electricity, and 340 MMBtus of hot water. The hot water was provided from the heat recovered from the engine-generator sets (from the hot water reservoir), and distributed to the scrubber through a hot water loop.

The yearly operation and maintenance costs were $13,740.

The total annual cost to own and operate the scrubber is $76,679.

Lessons Learned
During a typical system cleanout, the vessel is usually filled with water to flush out accumulated elemental Sulphur. During a cleanout in 2017, the vessel was filled with water, but unfortunately the fiberglass internal column through which biogas flows up to the top of the vessel in, was closed off at the top. With the vessel filled with water, the buoyancy of the internal column was such that it separated from the side of the vessel and cracked in the process. For future cleanouts, a clear description of the procedure including when to open and close valves has been developed.

Due to the cracking, all of the media had to be removed from the system when it was discovered that the buildup of elemental Sulphur was more extensive than expected, requiring intense manual labor to chip out and remove the encrusted media. To assist with future cleanouts, an additional access manhole was added to the side of the vessel (2017) to allow easier access and inspection of the media during cleanouts.

The original BTF system included 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. 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.

Before Sunnyside installed their BTF, they spent $23,896 per year on oil changes (750 hours between changes). After the installation of the BTS, $13,868 per year was spent (1,200 and 1,400 hours between changes) for a savings of $10,028 per year. The savings from reduced oil changes alone does not economically justify the BTF, however it is expected that more significant savings will be realized through increased intervals between more costly engine rebuilds. 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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