DEPARTMENT OF ENVIRONMENTAL SCIENCE & TECHNOLOGY

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Scrubbing H_2S from Farm-Based Anaerobic Digestion Systems

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Introduction

- Biogas produced from anaerobic digestion (AD) is a source of renewable energy, as it can be used for heat and power generation.
- High H_2S concentrations in biogas (0.05% - 1) are a major problem associated with the AD of sulfate-rich organic wastes.
- Reduction of sulfur-containing compounds, like sulfates and proteins, under anaerobic conditions by sulfate reducing bacteria (SRB) is the primary mechanism of H_2S production.
- Hydrogen sulfide acts as a corrosive agent and damages most equipment (pipelines, compressors, electric generator sets and gas storage tanks), adversely affecting their performance.

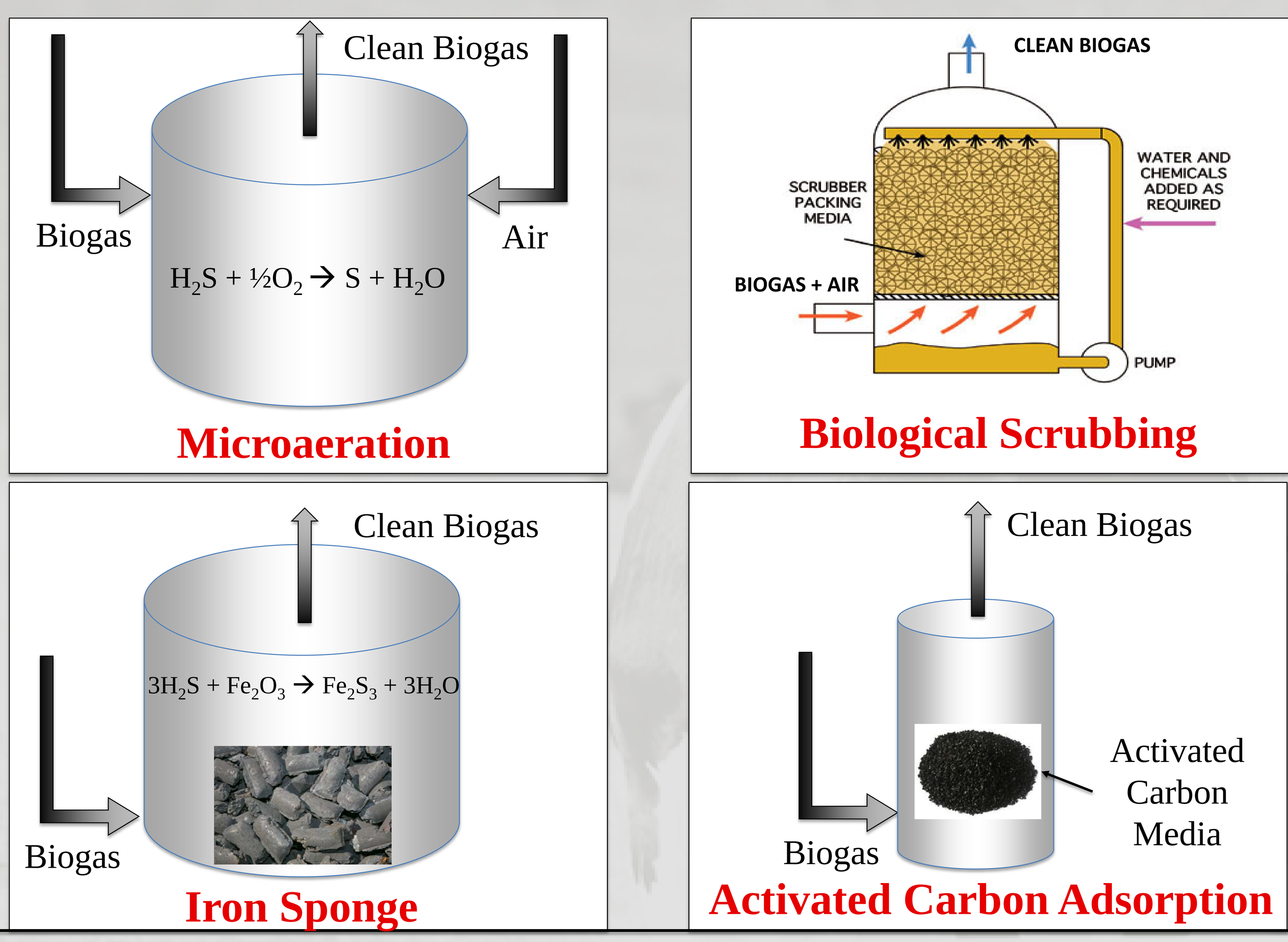
Figure 1. H_2S production from sulfate rich wastewater (left) and effects of H_2S induced corrosion in pipelines and generators (middle, right).

Market available H_2S scrubbers usually have high capital costs, operating costs, or unpredictable efficiencies. This study is conducted to provide dairy farmers with quantifiable advantages and disadvantages of different types of scrubbing systems.

H_2S Recommended Limits

Technologies	Hydrogen Sulfide Limits (ppmv)
Heating (Boilers) and Stirling Engines	< 1,000
Internal Combustion Engines	< 50 - 500 depending on the type of engine
Fuel Cells	< 1
Natural Gas Upgrade	< 4 (variations among countries)

Commercial H_2S Scrubbers



Objectives

The objectives of the project are to:

1) Understand H_2S scrubbing operational and maintenance parameters using data from Maryland and Pennsylvania farms,
2) Quantify the advantages and disadvantages of different types of scrubbing systems,
3) Obtain information on capital and operational costs associated with H_2S scrubbers on Maryland and Pennsylvania farms.

Methods

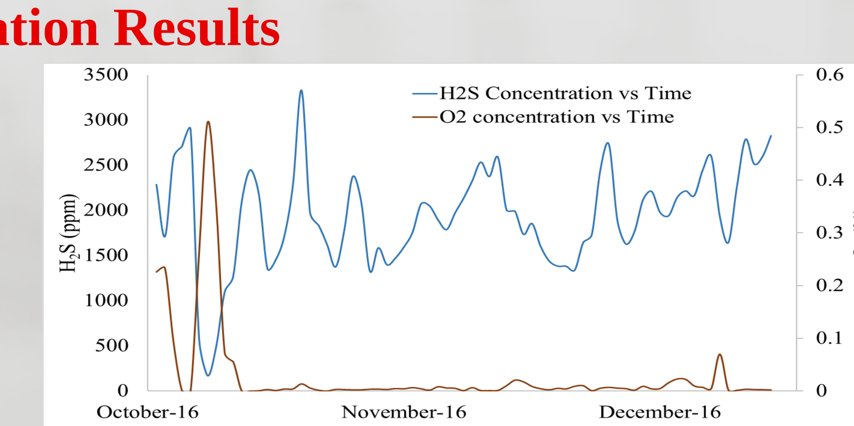
Biogas Analyzer | Iron Oxide Scrubber | Biological Scrubber

- Obtain CH_4, CO_2, O_2 and H_2S measurements using a Siemens Gas Analyzer for pre-scrubbed and post-scrubbed biogas
- Obtain financial information from farmer's records.
- Provide farmers with operational and efficiency information to obtain the best performance from their H_2S scrubbers.

H_2S Scrubbing Results

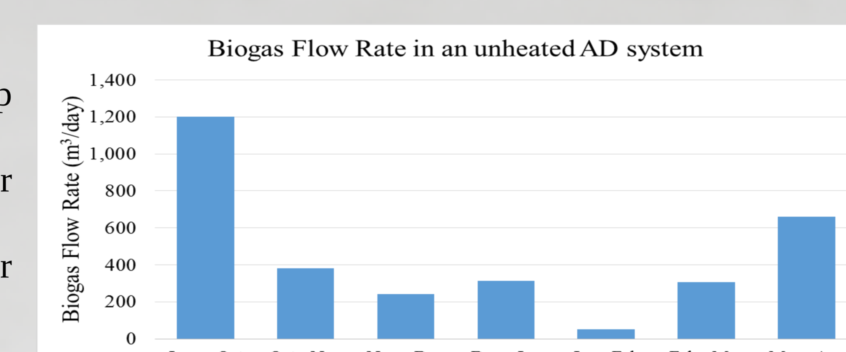
Microaeration Results

- H_2S concentrations drop below 200 ppm as O_2 concentrations increase in the biogas.
- Constant air flow rate was not efficient at handling variable H_2S concentrations in the biogas

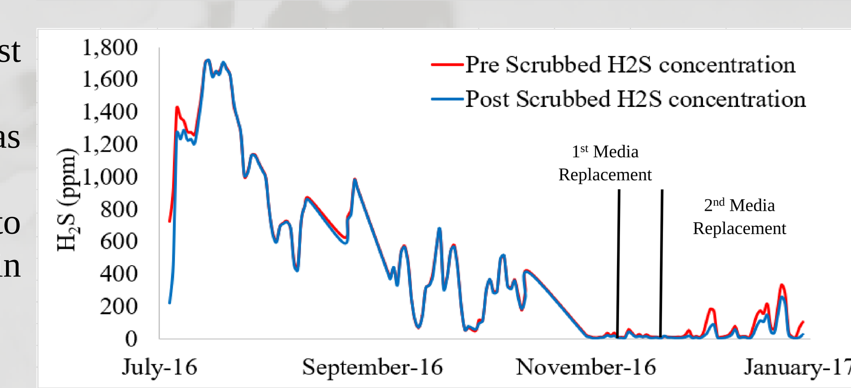


Iron Oxide Scrubber Results

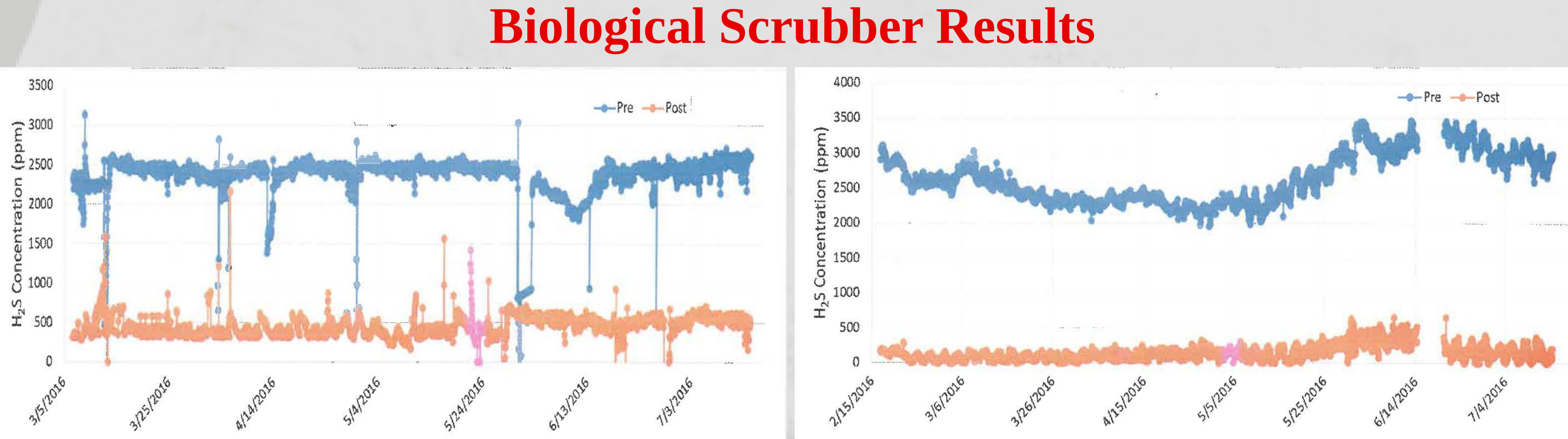
- Biogas flow rates decrease as the temperatures drop in an unheated AD system.
- However, the biogas can go back up to higher production rates as the temperature increases.
- Most farms have a heating system in their digester to prevent variable biogas flow rates.



- A treatment effect was initially observed in August for a short period of time.
- Due to saturation of the iron oxide media, there was no observed treatment till December
- A second media change in December, led to observable differences in the H_2S concentration in the treated biogas



Biological Scrubber Results



- A consistent treatment effect was observed for both biological scrubbing systems during the monitoring period.

H_2S Scrubbing Results

Scrubber Type		Biological Scrubber 1	Biological Scrubber 2	Micro-aeration	Iron Oxide Scrubber
Size	Avg. No. of Milking Cows	4,200	1,500	650	750
	Engine Generator Capacity (kW)	1,000	500	140	110
Performance	Average Untreated H_2S (ppm)	2,640 ± 350	2,350 ± 315	#	603 ± 51
	Average Treated H_2S (ppm)	150 ± 110	450 ± 190	1938 ± 23	585 ± 50
	Overall removal Efficiency (%)	94.5	80.1	#	3.0*
	Avg. Mass of H_2S removed (kg/hr)	2.37	0.35	#	0.0009
	Engine-Generator Capacity Factor	0.93	0.68	0.76	0.2

- * Low efficiency due to use of scrap iron media inside the scrubber that was saturated with H_2S.
- # Microaeration is an in-situ process for removing H_2S and so, untreated H_2S concentrations, overall efficiency and average mass of H_2S removed cannot be calculated.
- Variation in efficiency in the two biological scrubbers is due to differnces in maintenance and operational parameters.

Financial Results

Scrubber Type	Microaeration	Biological Scrubber 1	Biological Scrubber 2	Iron Oxide Scrubber
Farm Size	650 cows	4200 cows	1500 cows	750 cows
Generator Capacity	140 kW	1000 kW	500 kW	110 kW
Scrubber System Capital Cost	$450	$342,000	$185,000	$525
Annual Labor, Cleanout Costs	$0	$11,160	$4,340	N/A
Annual Generator Maintenance Costs	$28,708#	N/A	N/A	N/A
Annual Scrubber Maintenance Costs	$120	$7,495	$10,150	$1,150

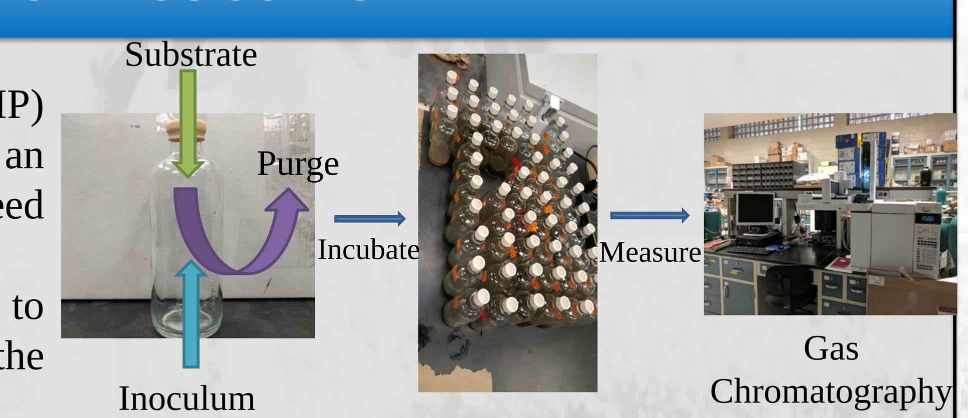
Includes oil change costs

Conclusions

- Microaeration, one of the cheapest biogas desulfurization techniques, may still lead to high generator maintenance costs due to inefficiencies and unreliable results.
- More research is required for optimization of this process in addition to the development of efficient, low-cost methods for biogas desulfurization.
- Proper maintenance operational control can lead to consistently high H_2S removal efficiencies in biological scrubbing systems.

Future Research

- Biochemical Methane Potential (BMP) test for experiments using biochar as an digester additive to eliminate the need for an additional desulfurization unit.
- Modification of biochar surface to enhance in situ H_2S removal from the biogas.



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