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Effect of biochar addition on H_2S production in an anaerobic digester

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Biogas Constituents

Compound	Chemical	Range %
Methane	CH_4	50-75
Carbon Dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0.01-5
Oxygen	O_2	0.1-2
Water Vapor	H_2O	0-10
Hydrogen Sulfide	H_2S	10-30,000 ppm
Ammonia	NH_3	0.01 – 2.5 mg/m^3

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Formation of H_2S and its effects

- Reduction of sulfur-containing compounds under anaerobic conditions by sulfate reducing bacteria (SRB) –> H_2S production
- H_2S is corrosive and damages pipelines, compressors, engine generator sets (EGS) and gas storage tanks

Corroded engine generator at a dairy farm

Corrosion after-effects

H_2S generated from sulfates in waste water

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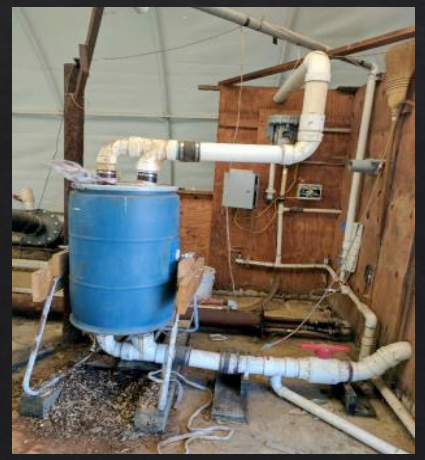
Hydrogen Sulfide Limits and Control Technologies

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

1. Biological Desulfurization
2. Iron Oxide Scrubbing
3. Activated Carbon Adsorption
4. Air Injection/Microaeration
5. Chemical Addition to the digester


Iron Oxide Scrubber


Biological Scrubber


Activated Carbon

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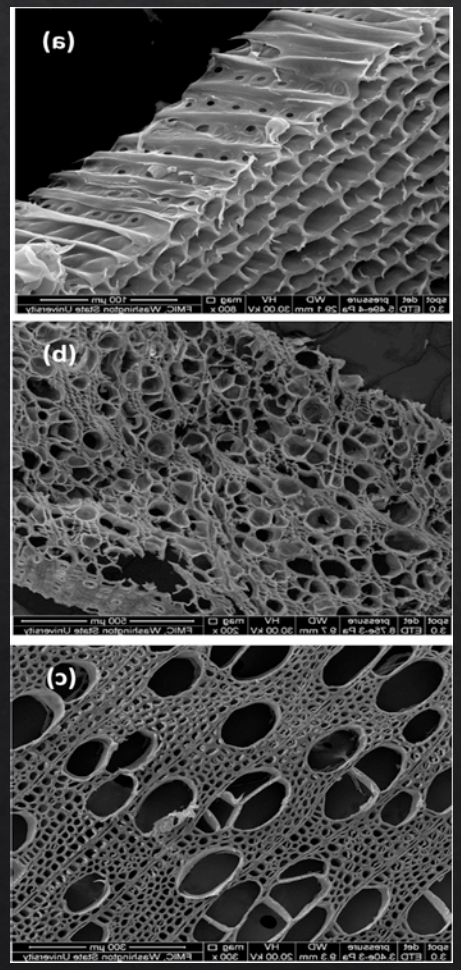
Biochar as an additive for H_2S reduction



SEM images of Douglas fir wood, bark and poplar wood. Suliman et al. (2016)

- Managing and operating external scrubbing systems require technical expertise and manpower that may be unavailable on smaller-scale farms.
- Biochar could be a possible low-cost and less labor intensive solution for H_2S removal, if added directly into a digester
- Previous work on direct biochar addition has shown some positive effects on CH_4 production and CO_2 sequestration in waste water sludge digesters
- Biochar has also been shown to be comparable or even better than activated carbon at H_2S adsorption from a biogas stream in an external scrubber

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Objectives

- Investigate the effect of direct addition of two types of biochar on CH_4 and H_2S production in lab-scale anaerobic digestion systems

Research Questions

- Does increasing the concentration of biochar lower the volume of H_2S produced in an anaerobic digestion system?
- Does the biochar type, mineral composition, and pH affect the H_2S production?

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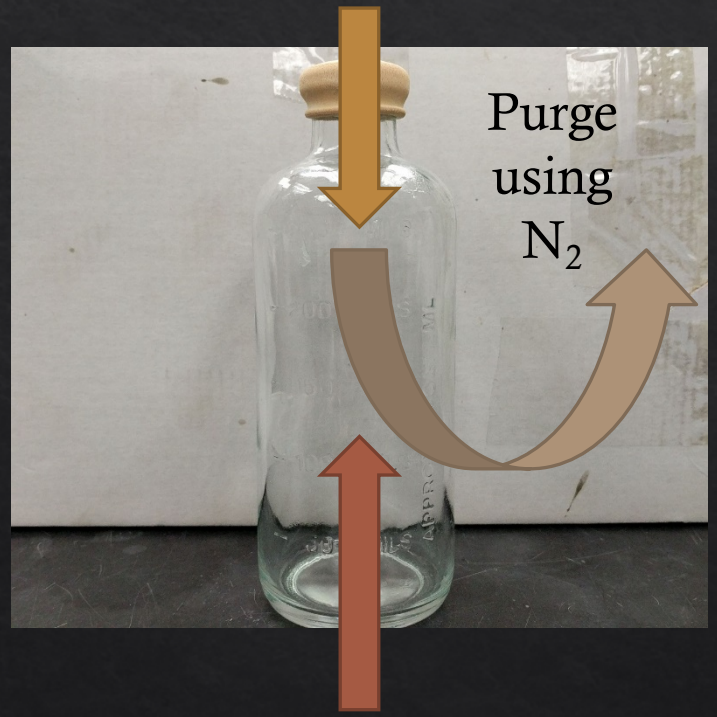
Lab Scale Reactor Tests

Substrate + Biochar



Inoculum

Lab Scale reactor bottle

Incubate

Full set of experimental units

Measure

Gas Chromatography

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Experimental Design (effect of biochar concentration)

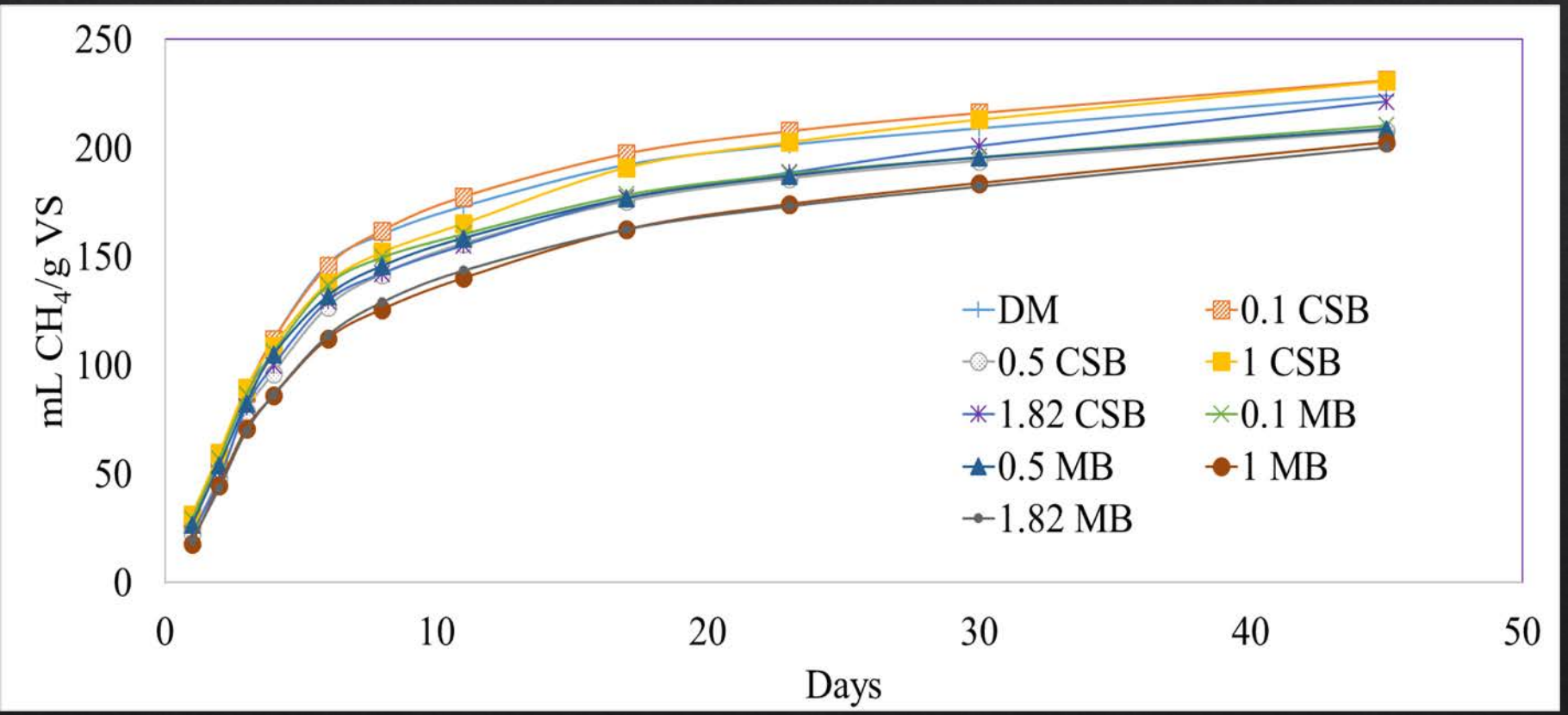
CONTENTS	Biochar amount added (mg)
Inoculum Control	
Manure Control (DM)	
0.1 g Corn Stover Biochar : 1 g TS of manure (0.1 CSB)	55
0.5 g Corn Stover Biochar : 1 g TS of manure (0.5 CSB)	277
1 g Corn Stover Biochar: 1 g TS of manure (1 CSB)	554
1.82 g Corn Stover Biochar: 1 g TS of manure (1.82 CSB)	1007
0.1 g Maple Biochar : 1 g TS of manure (0.1 MB)	55
0.5 g Maple Biochar : 1 g TS of manure (0.5 MB)	277
1 g Maple Biochar: 1 g TS of manure (1 MB)	554
1.82 g Maple Biochar: 1 g TS of manure (1.82 MB)	1007

- 3 replicates for each treatment
- Total volume of manure and inoculum: 200 mL
- Biochar obtained from ArtiChar prepared at 600 C and a 20 min residence time
- An inoculum : substrate (manure) ratio (ISR) of 2:1 was used on a volatile solids basis.

Biochar Mineral Results

	Corn Stover Biochar (CSB)	Maple Biochar (MB)
Total N (%)	1.16	0.79
Phosphorus (% P_2O_5)	0.55	0.19
Potassium (%K_2O)	2.98	0.57
Sulfur (%S)	0.04	0.02
Calcium (% Ca)	1.33	1.22
Magnesium (% Mg)	0.33	0.14
Sodium (% Na)	0.04	0.02
Zinc (ppm)	51	67
Iron (ppm)	6194	2659
Moisture (%)	1.67	1.82
pH	10.3	9.6

Results: CH_4 Production



- No significant differences in CH_4 concentration
- Cumulative CH_4 production varied from 200 – 231 mL/g VS, with 1CSB having the highest and 1MB having the lowest CH_4 volume.

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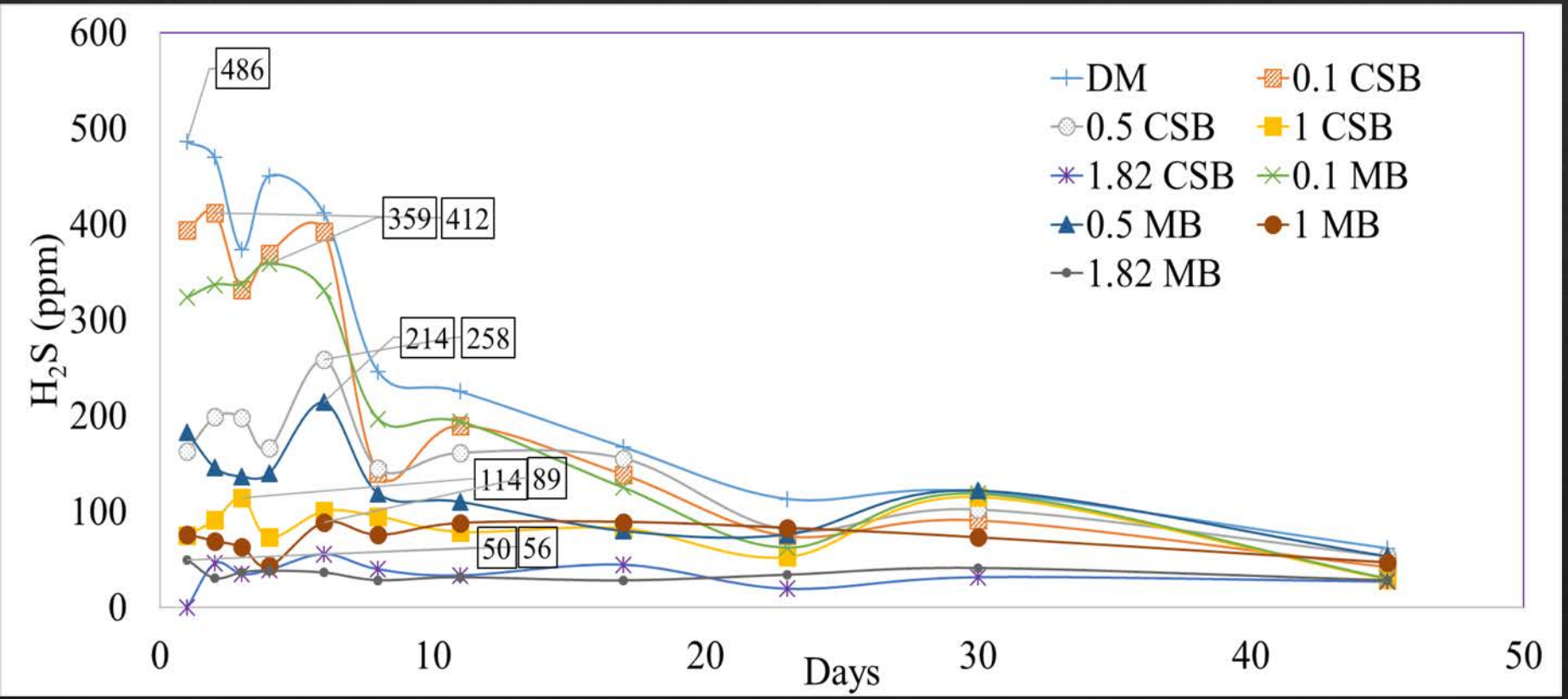
Results: Daily H_2S Production



- DM had the highest H_2S concentration during the study period
- Concentration of H_2S gradually decreased as the concentration of biochar increased
- H_2S concentrations at the end of the study were below 100 ppm for all treatments
- The labels denote the maximum H_2S concentration for each treatment

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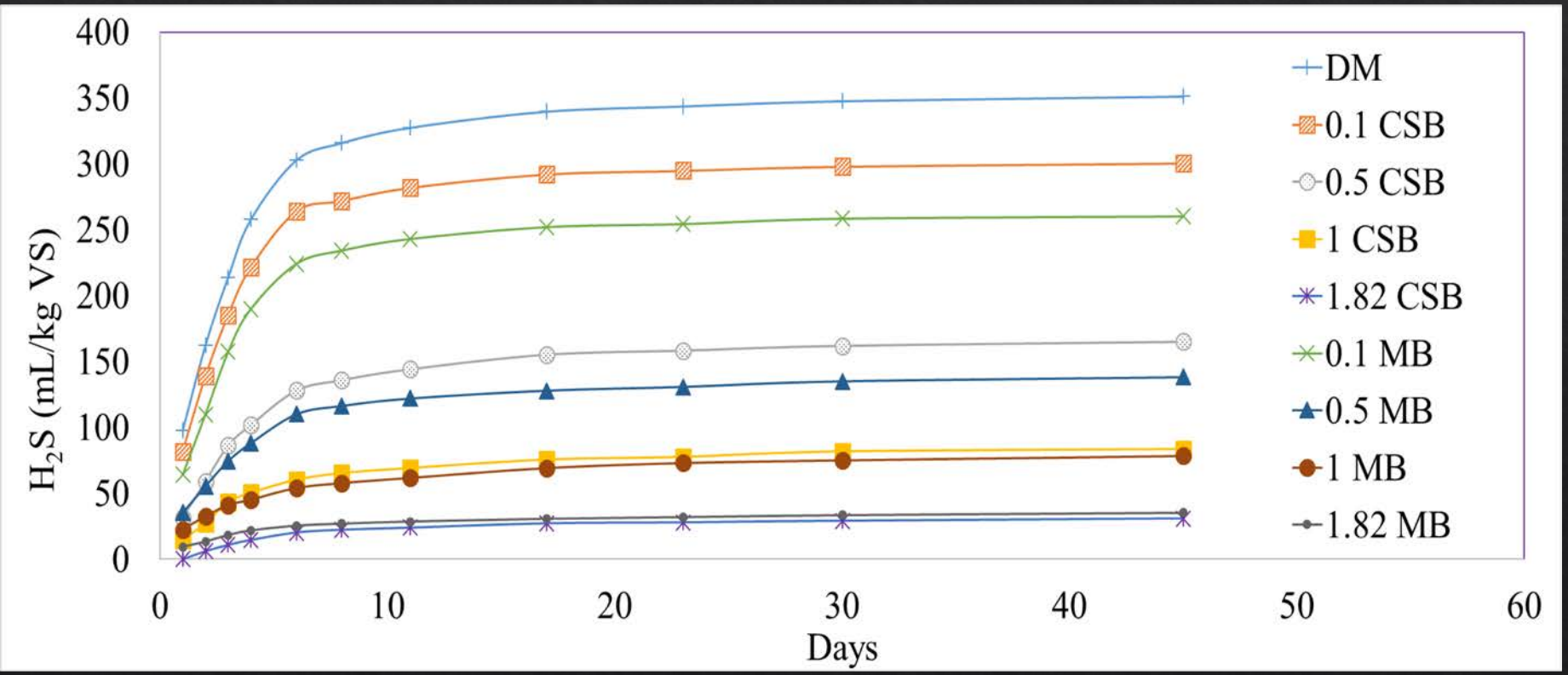
Results: Cumulative H_2S Production



- DM had the highest H_2S volume after the study period (351 ± 9 mL H_2S/kg VS)
- Volume of H_2S generated decreased as the concentration of biochar increased
- At the highest dose of biochar added (1.82 g biochar/g Manure TS), the % reduction in H_2S was 91.1% and 90.0% for CSB and MB, respectively

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Results: Biochar Adsorption

Treatment	H_2S volume reduction* (uL)	Normalized H_2S reduction (uL/g biochar)	Adsorption (mg H_2S/g biochar)
0.1 CSB	17.87	322.90	0.45
0.5 CSB	65.43	236.41	0.33
1 CSB	94.08	169.97	0.24
1.82 CSB	112.62	111.80	0.16
0.1 MB	32.00	578.19	0.81
0.5 MB	74.91	270.66	0.38
1 MB	95.89	173.25	0.24
1.82 MB	111.02	110.21	0.16

*When compared to DM control

Conclusions

- Biochar was effective in reducing H_2S in biogas and the % reduction increased with increasing amounts of added biochar
- There were no significant differences in % CH_4 between treatments
- H_2S adsorption capacity decreased as the amount of added biochar increased
- H_2S reduction efficiency increased to >90% for each biochar type (CSB and MB) at the highest dosage (1.82 g biochar/g manure TS)
- There were no significant differences in H_2S reduction between the two biochar types at higher doses

Current Projects and Research Questions

- How does particle size of the biochar affect the sorption of H_2S onto the biochar surface?
- Can a surface modified biochar increase the amount of H_2S adsorbed?
- Can biochar be used for N and P adsorption from dairy manure along with H_2S reduction in biogas?
- Is it better to add biochar directly into a digester or should it be used in an external gas filter column for H_2S removal?

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Thank You