Renewable biochar for hydrogen sulfide and nutrient reduction in anaerobic digesters

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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 hydrogen sulfide (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.

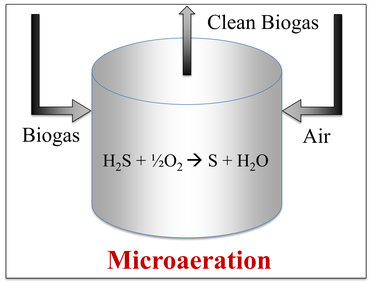
Figure 1. H_2S production from sulfate rich wastewater (left) and effects of H_2S induced corrosion in pipelines and generators (middle, right).

Market available H_2S scrubbers usually have high capital costs, operating costs, or unpredictable efficiencies. This study is conducted to investigate the possibility of using biochar as an alternate method for H_2S removal from biogas.

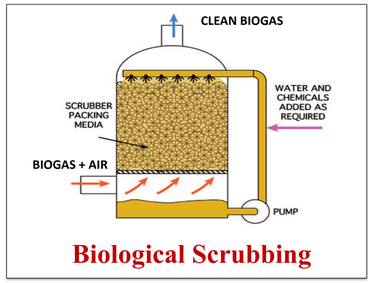
H_2S Recommended Limits

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)

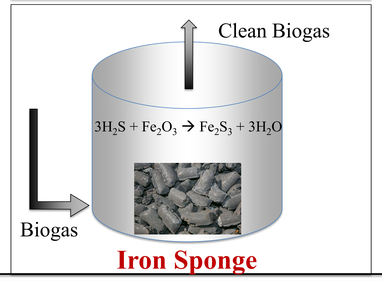
Commercial H_2S Scrubbers



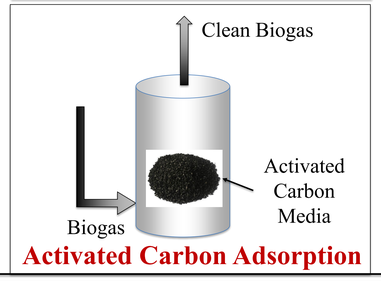
Microaeration



Biological Scrubbing



Iron Sponge



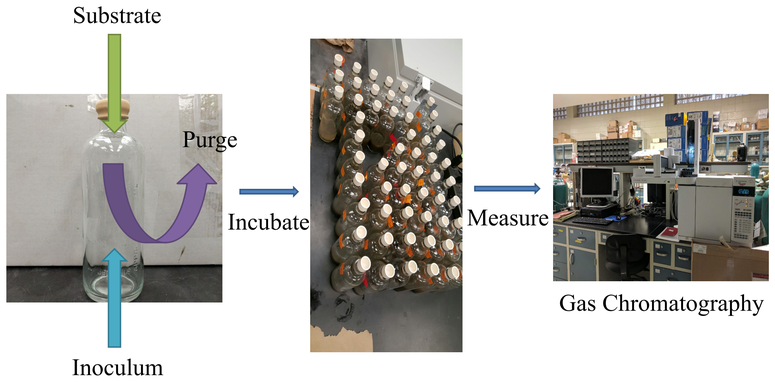
Activated Carbon Adsorption

Objectives

The objectives of the project are to:

1) Investigate the possibility of using biochar for desulfurization of biogas,
2) Investigate the effect of biochar particle size on the efficiency of biogas desulfurization,
3) Investigate additional benefits of biochar addition to a digester, such as removal of nutrients such as Ammonium nitrogen (NH_4-N) and dissolved phosphorus (P) from the liquid effluent.

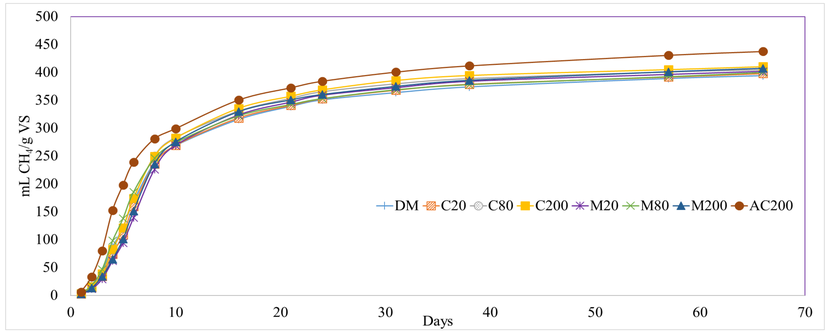
Methods



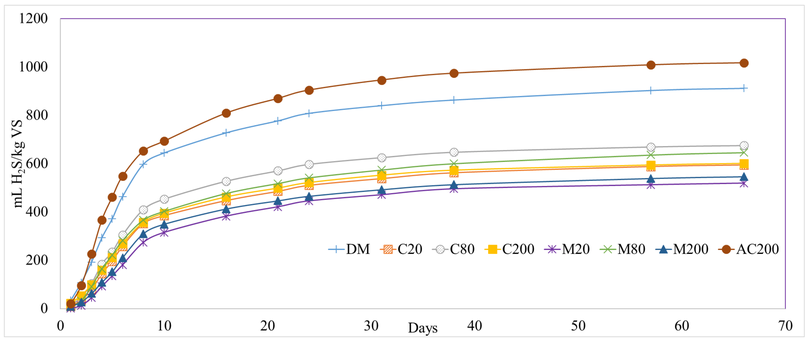
- Biochemical Methane Potential (BMP) test for experiments using biochar as a digester additive to eliminate the need for an additional desulfurization unit.
- Methane (CH_4), Carbon Dioxide (CO_2) and H_2S was measured using Gas chromatography.
- Dairy Manure (DM) along with three particle sizes (20, 80, 200) for two different biochar types Corn Stover (C) and Maple wood chips (M) were tested and compared to activated carbon (AC)
- Post digested effluent was tested for NH_4-N.

CH_4 Results

- CH_4 concentrations were not affected by the addition of biochar, when compared to DM digestion.
- AC addition, however, did lead to a 10% (p value < 0.05) increase in the biogas production.

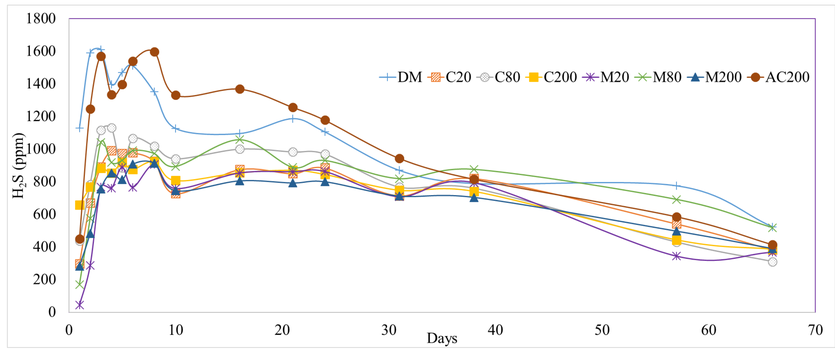


H_2S Results



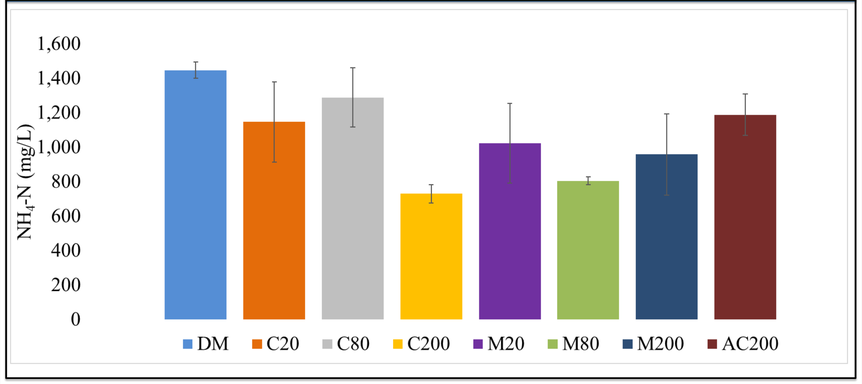
- 0.5g biochar per gram of manure total solids added led to a 26% - 43% reduction in total H_2S volume, when compared to DM digestion.

H_2S Results



- DM and AC amended treatment had a peak H_2S concentration of 1,600 ppm in biogas.
- Biochar amended treatments had a maximum peak H_2S concentration of 1,130 ppm for C80 treatment and a minimum peak H_2S concentration of 905 ppm for M20 treatment.
- All treatments exhibited similar H_2S concentrations at the end of the study, suggesting exhaustion of biochar capacity to uptake H_2S.

NH_4-N Results



Conclusions

- Biochar, at a concentration of 0.5 g/g of manure total solids was moderately effective in biogas desulfurization
- Biochar was also effective in reducing NH_4-N in the digester effluent, with a maximum reduction of 49.6% for C200 treatment.
- Differences in particle size did not affect the volume of H_2S removed.
- Biochar was more effective than AC in H_2S and NH_4-N reduction.

Future Research

- Tests to quantify the amount of P that can be absorbed by biochar from digester effluent.
- Identify and characterize the biochar qualities that can enhance H_2S, NH_4-N, and P removal.
- Modification of biochar surface properties to enhance in situ H_2S, NH_4-N, and P removal from the biogas.

Acknowledgements

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