University of Colorado Boulder

Fecal sludge treatment by pyrolysis: characterization of exhaust gas and odor treatment

Tesfayohanes Yacob, Richard Fisher, Ryan Mahoney, Josh Kearns, Barbara Ward, Scott Summers, Karl Linden, Alan Weimer

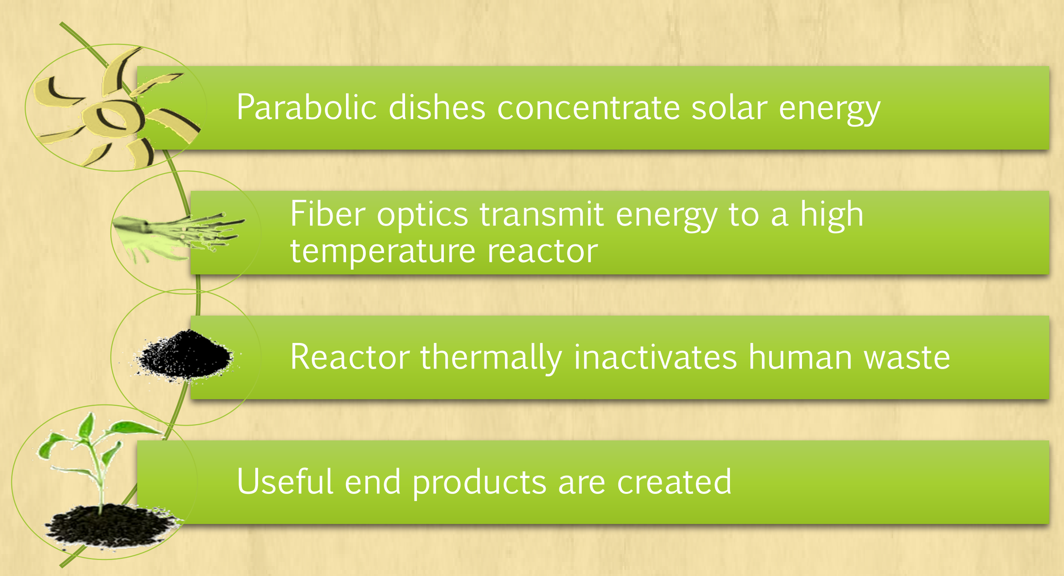
Sol-Char Toilet

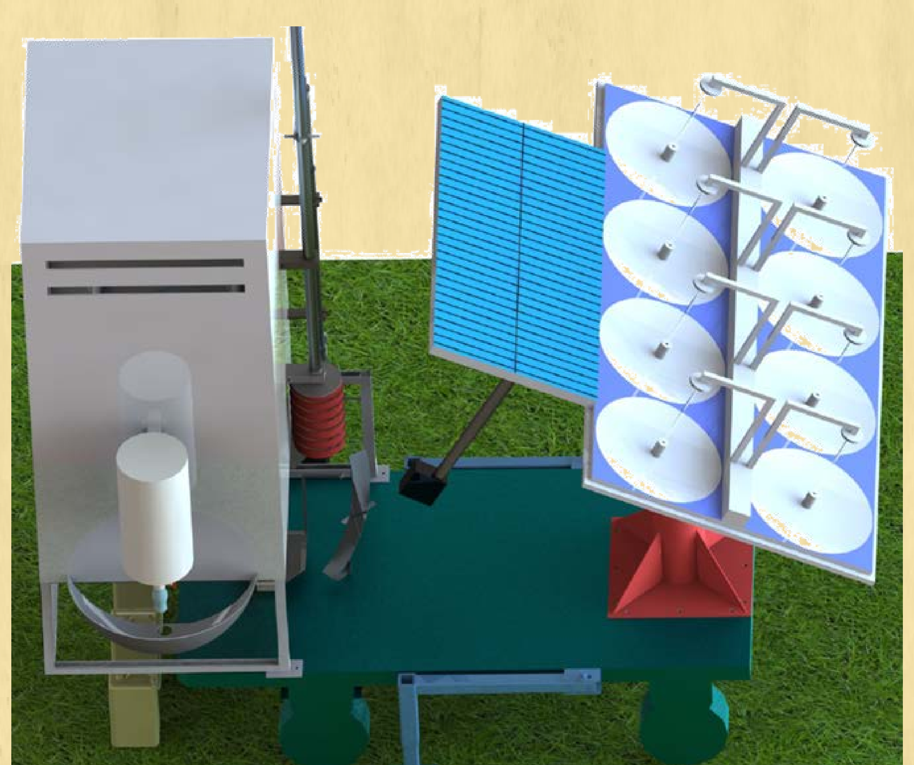
The Need

- Today, 2.5 billion people are without a form of improved sanitation
- Diarrhea kills more than 1.5 million people each year
- There is limited development of on-site fecal waste treatment technologies

The Solution

- A technology that:
  - Converts fecal waste to useful end products daily
  - Does not use grid electricity or flush water
  - Uses a renewable energy source: The Sun





Sol-Char Toilet
First Generation Prototype

Objective of study

- Quantify and characterize odor during pyrolysis of waste
- Characterize pyrolysis exhaust (tars + non-condensable gases)
- Evaluate odor treatment using biochar

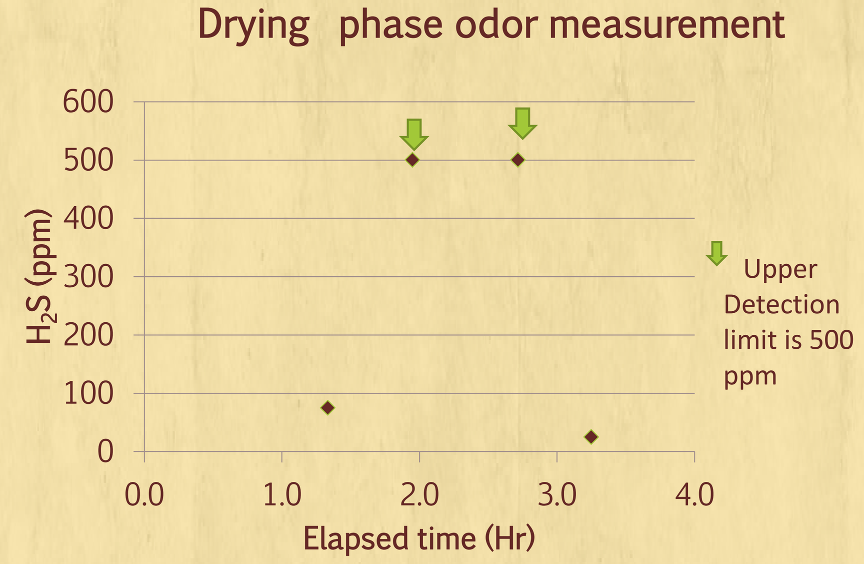
Quantify and characterize odor during pyrolysis of waste

Odor causing agents in human solid waste [1]

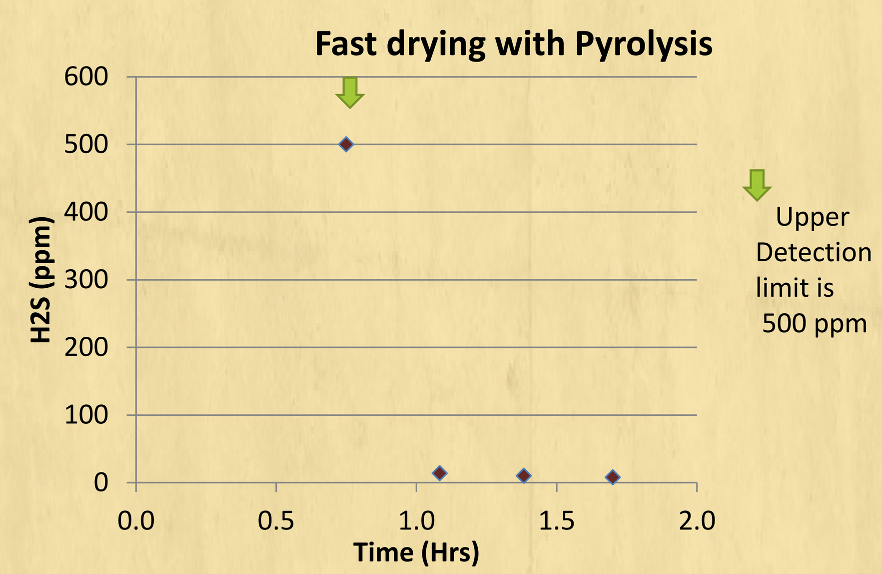
- Hydrogen sulfide, Methyl sulfide, methanethiol, dimethyl disulifde, dimethyl trisulfide.
- Skatol and Indole.

Odor measurement during waste drying and pyrolysis

- Designed prototype performs drying and pyrolysis in the same reactor, thus the need to understand odor associated with both.
- 78 g waste placed in stainless steel reactors and heated in furnace, exhaust from reactor cooled to remove condensable tars and liquids, and filtered through cotton to ensure complete condensation before being measured by H2S sensors. H2S is known to correlate well with odor[2].
- Furnace set at 300 °C, this allowed longer time for the waste to dry and quantify odor.



- Furnace set to 750 °C
- This allows shorter and faster drying period followed by pyrolysis.

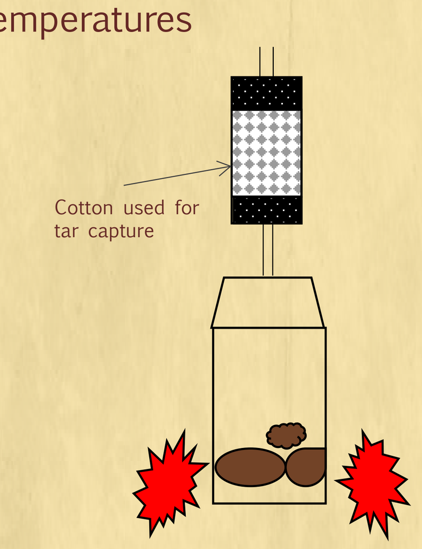


- There was clear difference between drying phase and pyrolysis phase with the drying phase having more H_2S content. The duration of these phases will depend on the rate of heat input to the reactor.

Characterizing pyrolysis exhaust (tars and non-condensable gases)

How much tar is expected from fecal sludge pyrolysis?

- Fecal sludge from volunteers dried and ground to < 400 um size,
- Pyrolyzed at 300 °C and 500 °C, 2.5 °C/min, hold time of 7.5 hours at the target temperatures



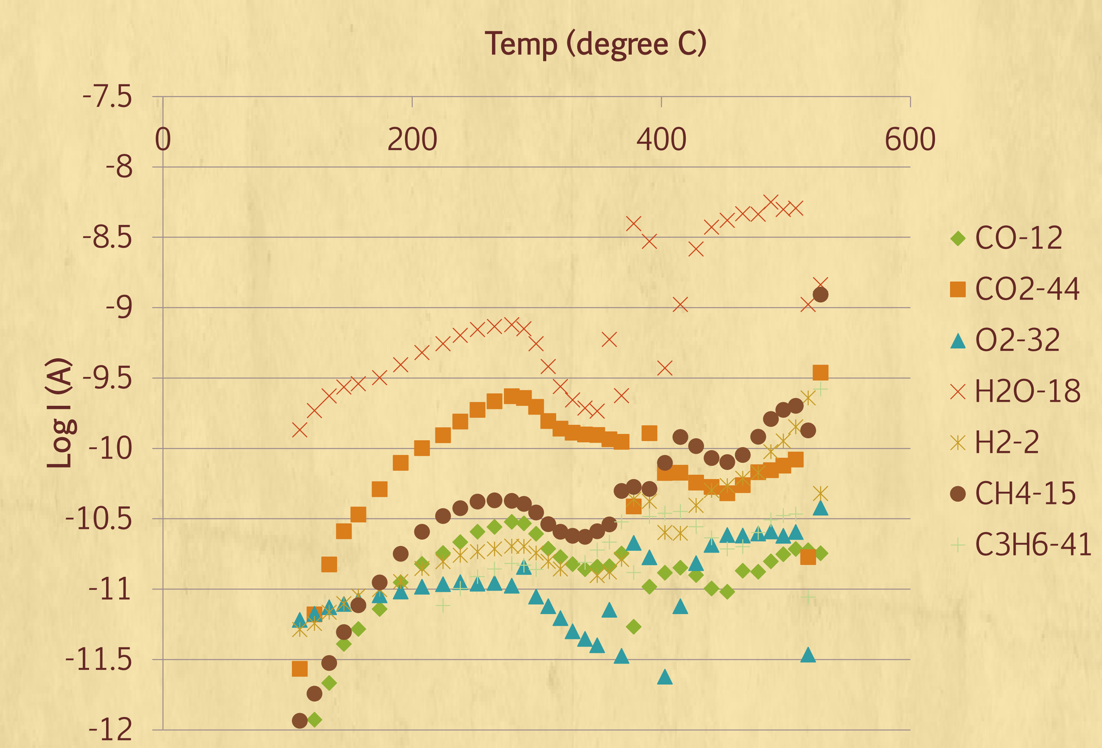
Schematics of tar capture set up

- Tars condensed on cotton filters and quantified by weight difference, char produced measured, non-condensable gases calculated by difference. Tar mass % yields shown below are based on dry fecal sludge mass.

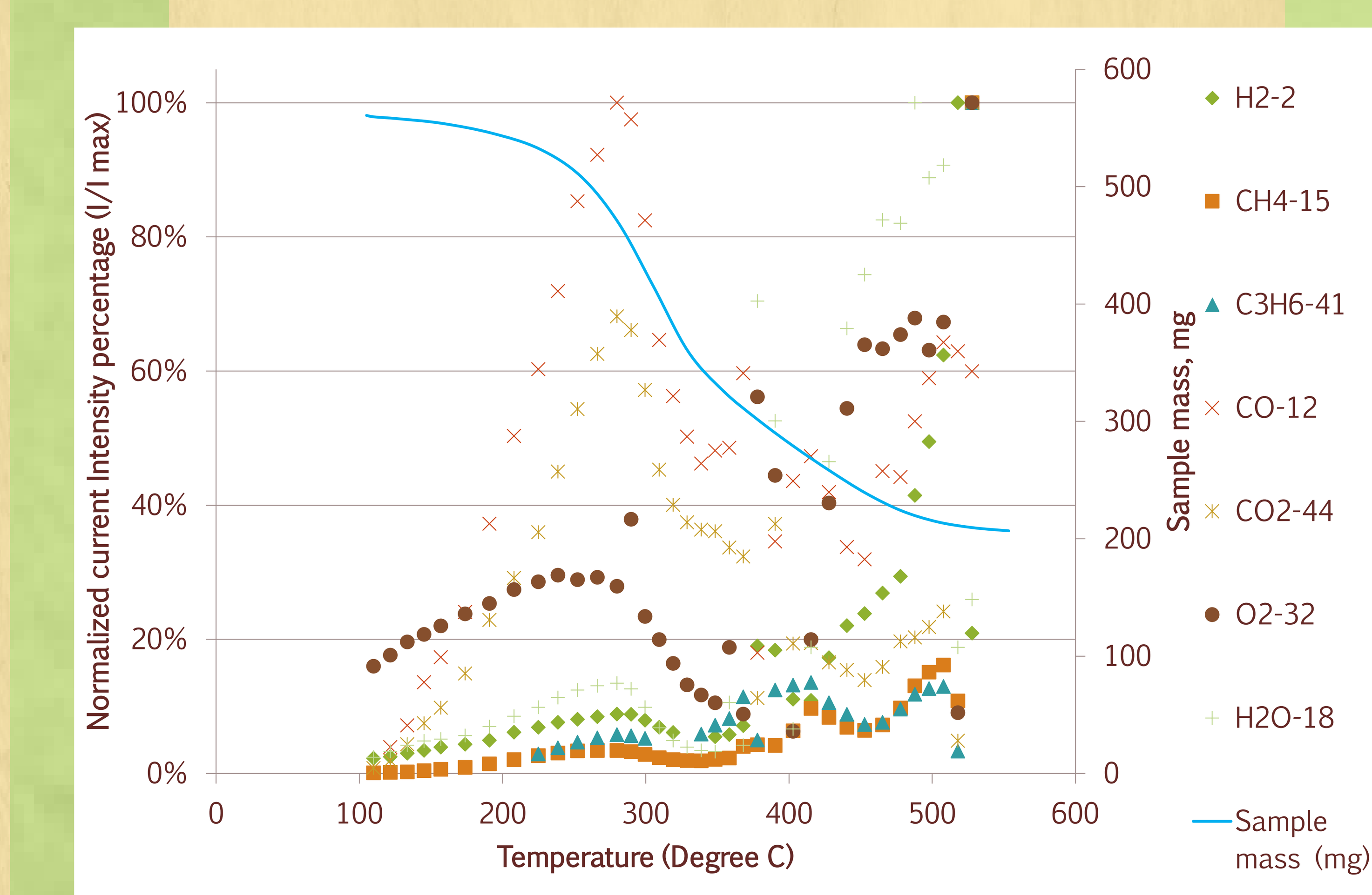
Temperature (°C)	Char yield %	Tar yield %	Gas yield %
300 °C	55.6 ± 3.1	33.0 ± 5.4	10.4
500 °C	48.0 ± 3.5	26.7 ± 2.5	26.3

Thermogravimetric analysis to detect pyrolysis gases

- 3.2 g waste used
- Waste heated to 10K/min till 105 °C and kept at that temperature for 2 hours
- Then heated to 550 °C at 10K/min.
- TGA run done under 20 SCCM argon atmosphere
- Evolved gases analyzed with attached Mass Spectrometer



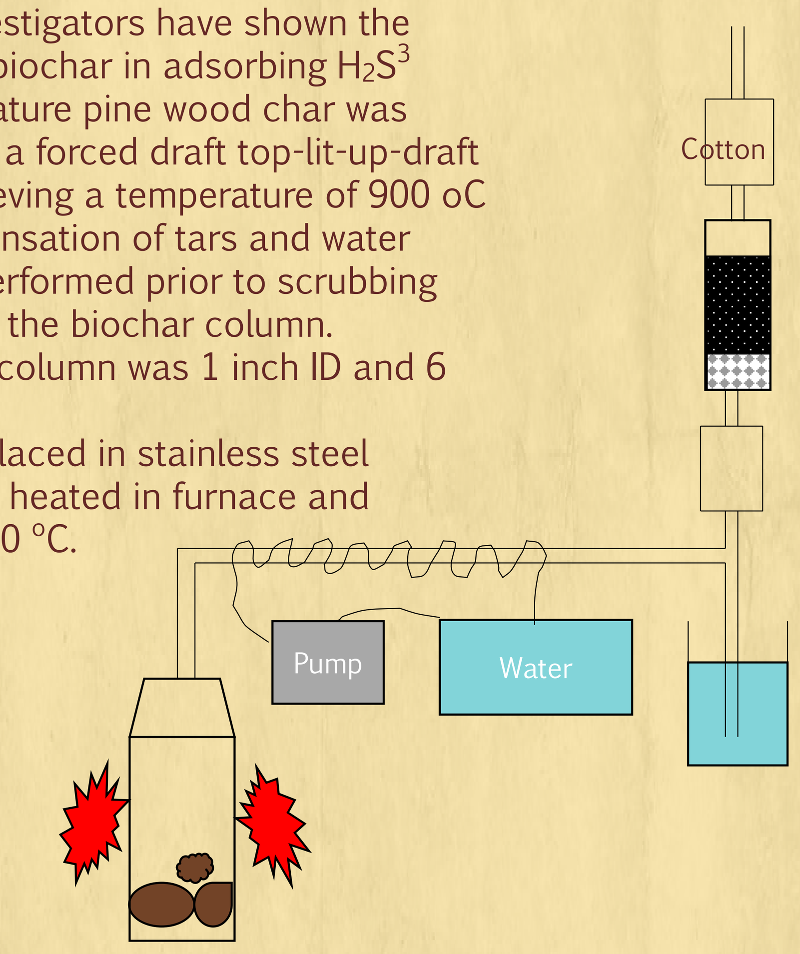
- Results Indicated gases of potential fuel use are present.
- H_2 concentration increased at a higher rate than CH_4 between temperatures of 350 to 500 °C.
- Water vapor was present even at higher temperatures despite 2 hour drying at 105 °C.



Odor treatment using biochar

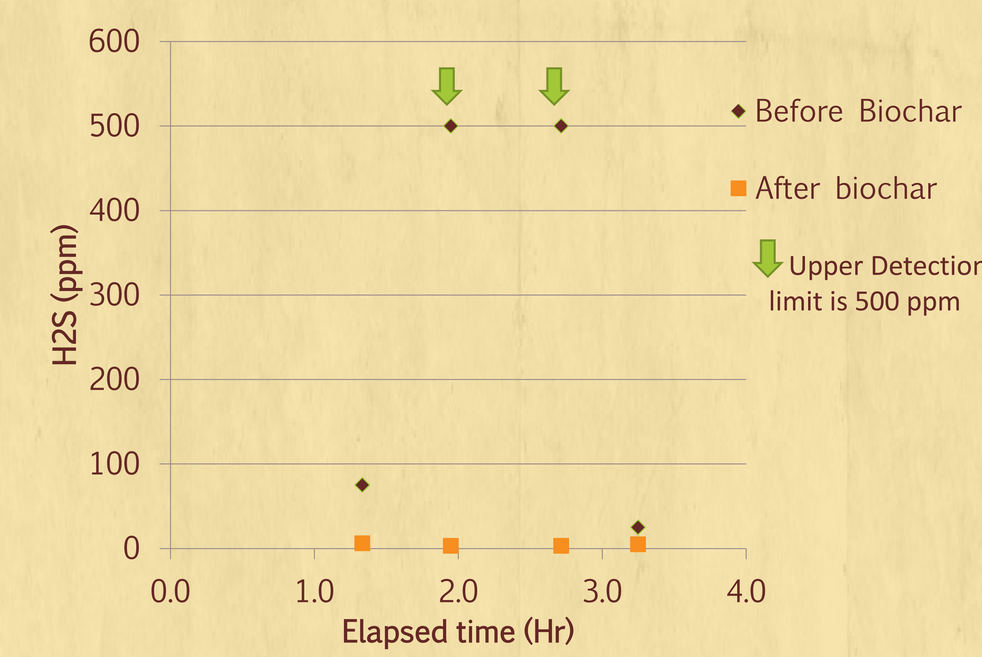
Laboratory experiments to evaluate odor treatment

- Previous investigators have shown the potential of biochar in adsorbing H_2S[3]
- High temperature pine wood char was generated in a forced draft top-lit-up-draft gasifier achieving a temperature of 900 oC
- In line condensation of tars and water vapor was performed prior to scrubbing the gases by the biochar column.
- The biochar column was 1 inch ID and 6 inch high .
- 78 g waste placed in stainless steel reactors and heated in furnace and heated to 300 °C.



schematics of odor treatment experiment

- Results indicated successful reduction of H_2S levels to < 1 ppm by the biochar.
- Slight discoloration (yellowish) of the biochar was observed suggesting possible adsorption of non odorous hydrocarbons.



Conclusions

- Drying of waste is the main contributor of odor during the treatment process.
- High Temperature wood biochar was demonstrated to reduce H_2S concentration to < 1 ppm.
- Gases of energy value such as H_2 and CH_4 were shown to be present. The presence of H_2O even at a higher temperatures will likely present the need for pre-treatment prior to use of gases.
- Tar mass yields of 33 and 26% were shown for 300 and 500 °C pyrolysis temperatures respectively.

References

1. Moore, J. G., Jessop, L. D., & Osborne, D. N. (1987). Gas-chromatographic and mass-spectrometric analysis of the odor of human feces. *Gastroenterology*,*93*(6), 1321-1329.
2. Koe, L. C. (1985). Hydrogen sulphide odor in sewage atmospheres. *Water, Air, and Soil Pollution*, *24*(3), 297-306.
3. Shang, G., Shen, G., Wang, T., & Chen, Q. (2012). Effectiveness and mechanisms of hydrogen sulfide adsorption by camphor- derived biochar.Journal of the Air & Waste Management Association, 62(8), 873-879..