SEWAGE SLUDGE CONVERSION TO RENEWABLE FUEL

Vince Cataldi, Joseph Sindlinger, Ethan Zimmerman

INTRODUCTION

Sewage sludge volumes and energy demands are both worldwide issues. Sewage sludge can be converted into a renewable biochar through hydrothermal carbonization, addressing both issues.

Sewage Sludge + Energy Demands = Need for Renewable Fuels

Hydrothermal Carbonization (HTC): a process converting wet biomass into a carbon-rich biochar using a series of chemical and thermodynamic processes.

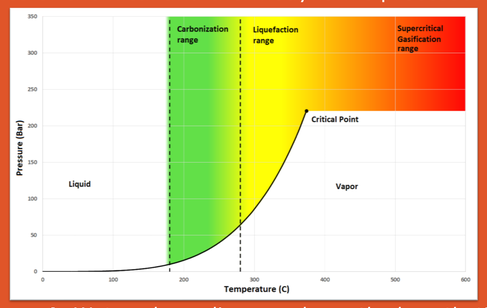

Figure 1: *Water-phase diagram shows the hypothetical carbonization range. HTC uses water to catalyze the reactions, while steam given off by the water pressurizes the system.*

METHODS

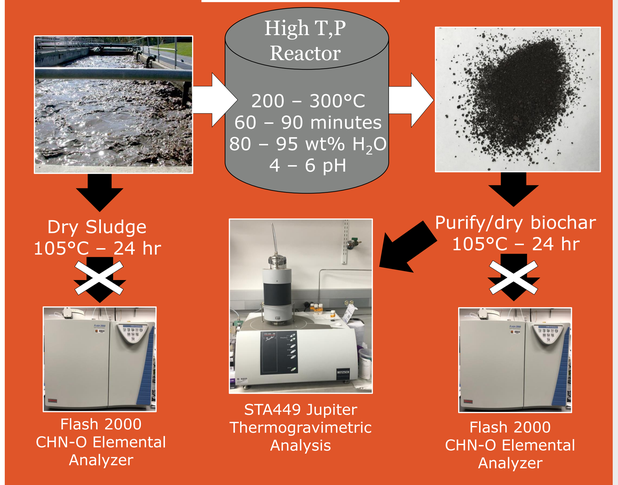

Figure 2: *Overview of HTC process steps (white arrows) and sludge/biochar analysis steps (black arrows) used to conduct and characterize the hydrothermal carbonization process. The Elemental Analyzer was not functional during our project, thus the white x's are used to denote that issue.*

Oregon State University

Objective: *C*onvert sewage sludge from the Corvallis City Public Works wastewater plant to a renewable biochar with a Higher Heating Value (HHV) in the range of *14 to 30 MJ/kg*, through hydrothermal carbonization.

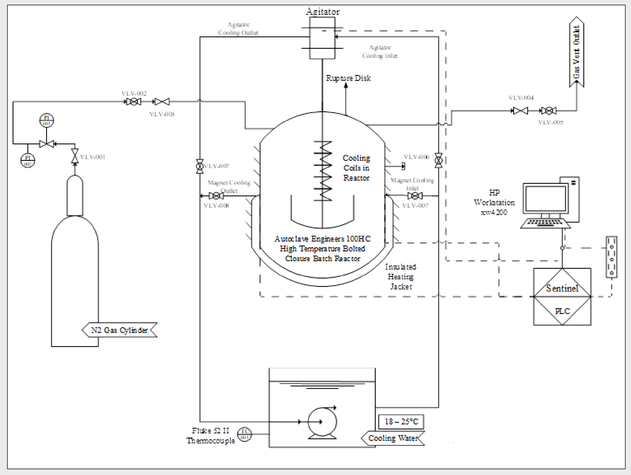

Figure 3: *Process flow diagram for the batch carbonization process. Ice was added to the cooling water bucket to maintain the temperature between 18 – 25 °C.*

Table 1*: Experimental parameters used for the 9 reactor runs. All runs were adjusted to a pH of 5 with sulfuric acid. Max pressure reached during each run was recorded.*

Experimental Parameters				
Run	*Temperature [C]*	*Time [min]*	*Moisture Content [wt% H2O]*	*Max Pressure [psig]*
1	250	45	90	600
2	250	45	90	668
3	250	45	90	619
4	225	75	90	372
5	225	75	80	420
6	225	90	80	374
7	225	120	90	385
8	225	180	90	378
9	225	480	90	384

RESULTS

Table 2: *Conversion data, and calculated LHV values for runs which were tested with TGA/DSC. Dirt mass was lost in the liquid pour off and stuck to the reactor walls, which had to be cleaned before each run.*

Results							
Run	*Initial Sludge Mass [g]*	*Final Biochar Mass [g]*	*Char Conversion [%]*	*Final Dirt Mass [g]*	*Enriched Dirt Conversion [%]*	*Mass lost [g]*	*LHV [MJ/kg]*
1	20.02	2.53	12.64	5.64	28.17	11.85	5.6 7.9 7.4
2	19.97	1.08	5.41	4.16	20.83	14.73	1.7
3	19.98	0	0.00	5.1	25.53	14.88	1.3
4	40.06	0	0.00	12.27	30.63	27.79	
5	44.08	0	0.00	17.34	39.34	26.74	
6	43.89	0.1	0.23	14.57	33.20	29.22	
7	20	0.61	3.05	9.21	46.05	10.18	
8	20.03	0.31	1.55	4.21	21.02	15.51	
9	20	0.39	1.95	7.83	39.15	11.78	
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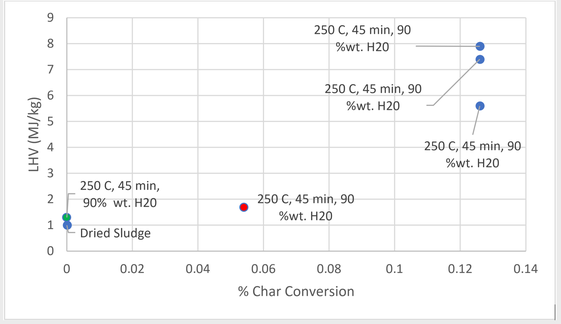

Figure 4: *Chart of LHV values vs. % char conversion for runs 1 – 3. Triplicate TGA/DSC runs were done on run one, shown at 13% conversion in blue. Run two is shown in red, and run three in green. Unprocessed dry sludge with an LHV of 1 MJ/kg is shown for comparison.*

The conversion of dried sewage sludge to biochar reached a maximum yield of **5%.** This was well below the literature values of 60-80% biochar conversion. The LHV value, or the energy content of the biochar, had a max of **7.9 MJ/kg**, which was below the expected range of 14-30 MJ/kg.

Oil products were found after processing which suggests hydrothermal liquefaction is occurring, reducing the biochar conversion and the LHV values.

DISCUSSION

Why is the biochar conversion and LHV low?

Primary Reasons
1. High Temperature
2. Short Residence Time
3. Degradation of the feedstock

Both the biochar conversion and LHV values found after testing were much lower than values found in literature.

This discrepancy is believed to be because the team ran the HTC process at high process temperatures, which catalyzed liquefaction reactions. These liquefaction reactions form other products and that were contained in the liquid product which was not measured.

The team also had short run times (between 45 minutes to eight hours) due to logistical impediments. Another literature review suggests that running the HTC process at residence times above eight hours could further increase yields and LHV.

One last project issue to note is that the team was able to determine the DSC produced LHV values accurate by ± 0.5 MJ/kg. However this accuracy was based off of one replicate, thus further testing of the ability of the DSC to measure LHV is required.

RECOMMENDATIONS

HTC is not recommended for processing sewage sludge at process time less than eight hours.

The process has low mass conversion with that mass having little energy content, thus the process is operating at a large energy loss.

FUTURE WORK

1. Continue HTC processing that focuses on characterizing the effects of temperature and process time on the LHV and mass yield of biochar products. Test temperatures between 225°C–250°C and process times above eight hours.

2. Use a standard with a species that has a known LHV to verify the accuracy of the DSC to measure a LHV.

ACKNOWLEDGEMENTS

- *Corvallis City Public Works:* Sewage sludge.
- *John Cochran and Andy Brickman:* Setting up the High T and P reactor.
- *Alexander Dyall:* TGA/DSC support.
- *Dr. Radniecki:* Use of his GLSN 009 oven dryer.
- *Dr. Nick AuYeung:* Use of TGA/DSC system.
- *Dr. Greg Rorrer:* Use of Flash 2000 Elemental Analyzer
- *Dr. Phil Harding:* Support and guidance.