NM WRRI Student Water Research Grant Final Report

1. Student Researcher: Carl Abadam
   Faculty Advisor: Anjali Mulchandani

2. Project title:

   "Hydrothermal Liquefaction of Wastewater Sludges for Energy Resource Recovery"

3. Description of the research problem and research objectives.

   This study aims to identify how variabilities in wastewater process configurations impact the biocrude yields from sludges processed and stabilized by hydrothermal liquefaction. Clean and renewable energy sources are vital to ensure a sustainable future. However, the current consumption of fossil fuels limits the ability to achieve this goal. Hydrothermal liquefaction (HTL) is a thermochemical process that converts wet biomass to valuable biocrude oil and biochar while reducing solid masses. Wastewater sludges were sampled across three facilities with varying influent design capacities and biological treatment configurations. Lipids extracted via solvent extraction and biocrudes produced from HTL were determined gravimetrically. Relative ester content was analyzed using gas chromatography. Results found that primary sludges from the sampled facilities yielded up to 44% higher mass of biocrude than waste-activated sludges. Additionally, the relative ester content of C16:0 - C18:3 fatty acids from lipids and biocrudes revealed statistical similarities across the sludge types and facilities. This suggests that HTL produces a biocrude whose yield is influenced by sludge treatment process configuration, but ester quality remains similar across facilities. These results help discover how biocrude products from HTL of wastewater sludges are impacted as specific wastewater processes vary and emphasize the valorization of wastewater sludge as a resource for energy resource recovery.

4. Description of the methodology employed.

   Sludge samples were collected from three wastewater facilities in New Mexico as shown in Figure 9. PS and WAS sludge from the Albuquerque facility (combined sludge was simulated as 1:1 PS and WAS sludge), PS and WAS from the Santa Fe facility, and WAS from the Los Lunas facility. Raw sludge was sampled in 10-liter Nalgene containers and stored in a refrigerator at 4 ˚C. Lipids from dried sludge samples were extracted using Soxhlet-solvent techniques. Approximately 0.5 grams of dry sludge sample were placed

inside a Whatman cellulose thimble (10 mm x 50 mm) and then into the Soxhlet extractor. HTL experiments were performed using a Parr 4565 Mini Bench Top Reactor consisting of a 100 mL T316 stainless steel vessel. PTFE gaskets were used to seal the reactor head to the reactor vessel, and an Alloy C-276 rupture disk prevented over pressurizing of the reactor. The maximum allowable working pressure of the reactor was 20.7 MPa (3000 psi) and 350 ˚C, respectively. A Parr 4848 reactor controller regulated the speed of the internal impeller and monitored the temperature via a Type J thermocouple. FAME peaks were identified using a Shimadzu GC-2012 Gas Chromatograph (GC) with a flame ionizing detector (FID). In addition, a Shimadzu AOC-20s auto-sampler and AOC-201 auto-injector were used to introduce samples into the GC. An Agilent BD-EN141 column (30.0m x 0.32 mm x 0.50 µm) with acid-modified polyethylene glycol (PEG) stationary phase was used. Figure 1 outlines the overview of the experimental procedure.

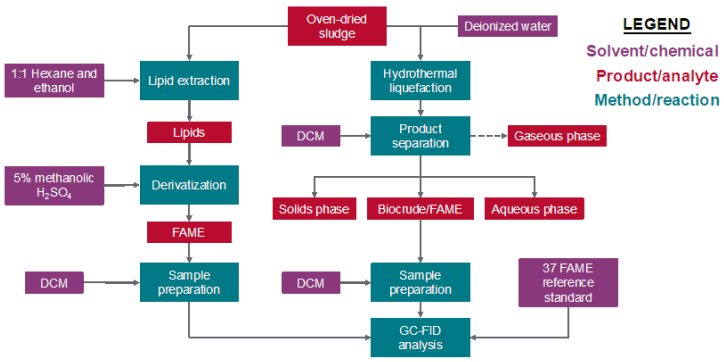

Figure 1 Methods Overview

5. Description of results; including findings, conclusions, and recommendations for further research.

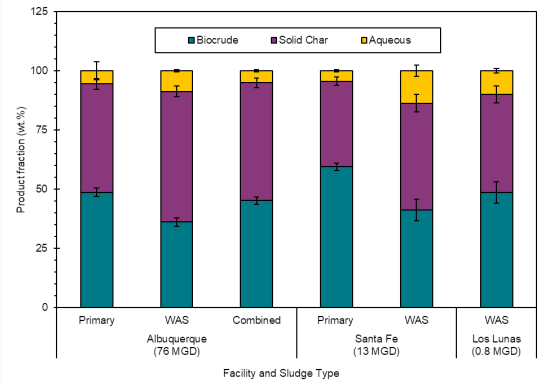

Figure 2 HTL Phase Distribution

Overall, we find that the biocrude yields from HTL of the observed sludges are higher for primary wastewater sludges and lower after biological treatment due to the decrease in lipid content, which is also affected by solids residence times of different sludges; however, ester content across the sludges is similar, still indicating a potential for a high-quality biofuel, independent of influent design capacities and biological treatment configurations.

We did not see the same distribution of C16 - C18 fatty acids in the biocrude as did in the lipids. Unlike other research on HTL of wastewater sludges, this research attempts to characterize the FAME quality, where research typically lumps all esters into one category. Despite this observation, we found all sludges yielded high relative areas for C22:2. This result is not identified in any other paper of HTL on wastewater sludges.

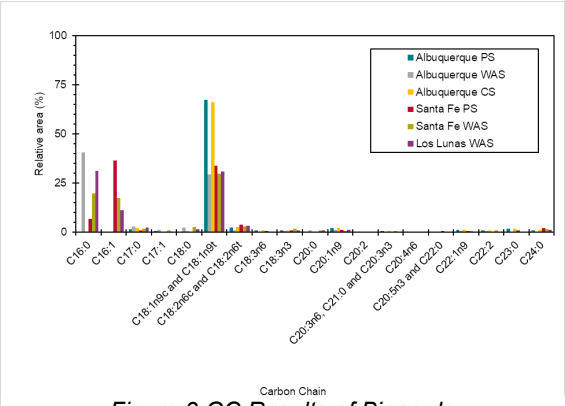

Figure 3 GC Results of Biocrude

Future research should explore how other parameters unique to each facility might impact biocrude yields and quality, particularly nitrogen and phosphorous, because of the variability of nutrient removal configurations in the liquid treatment train.

6. Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.

   This research is unique in that we used sludges from local wastewater facilities located here in New Mexico: Albuquerque Bernalillo County Water Utility Authority, Santa Fe Paseo-Real Wastewater Treatment Plant, and Los Lunas Wastewater Treatment Plant. Not only does this research seed the beginning for any future research with the utilities, such as sludge stabilization and energy recovery, we might also start the discussion for including hydrothermal technologies for new plants.

7. Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after December 14, 2023, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu)

   In addition to salary, the funds were used for travel costs to attend the 2023 Association of Environmental Engineering and Science Professors conference in Boston, MA.

Costs and Purchases	Amount
Salary	$6,000.00
Fringe Benefits	$480.00
Travel	$1,020
Total grant remaining	= $0.00

8. List presentations you have made related to the project.

   - NMWRRI Conference 2022
   - RMSAWWA Conference 2022/23

9. List publications or reports, if any, that you are preparing. For all publications/reports and posters resulting from this award, please attribute the funding to NM WRRI and the New Mexico State Legislature by including the account number: NMWRRI-SG-FALL2022.

   We are preparing this research for manuscript submission to the Bioresource Technology Journal.

10. List any other students or faculty members who have assisted you with your project.

Alejandro Espino Buiza was a visiting scholar from Peru and worked on the project with Carl over the summer in 2022. Derek Belka, a graduate student in the same program has also contributed.

11. Provide special recognition awards or notable achievements as a result of the research including any publicity such as newspaper articles, or similar.

    This research has led to Carl receiving an NSF GRFP award, and has led to winning second and third places at two RMSAWWA conferences. Additionally, Carl is presenting this work at this year's American Chemical Society's Spring conference.

12. Provide information on degree completion and future career plans. Funding for student grants comes from the New Mexico Legislature and legislators are interested in whether recipients of these grants go on to complete academic degrees and work in a water-related field in New Mexico or elsewhere.

    Carl Abadam successfully defended and submitted his master's thesis, "Hydrothermal Liquefaction of Wastewater Sludge for Energy Resource Recovery,". He is continuing his academic endeavors with a PhD in environmental engineering at UNM. This research has also led to him being awarded the prestigious NSF GRFP award. His plans are to continue researching solutions that benefit real users and to continue educating and engaging with his local community about water and wastewater technologies.