Investigation of Waste-Based Feedstocks for Sustainable Aviation Fuel Production

OBJECTIVE AND SIGNIFICANCE: The aviation industry (civilian and military) faces significant challenges due to dependence on petroleum jet fuels and limited opportunity for electrification. Sustainable aviation fuels (SAF) from renewable resources provide alternatives to petroleum fuels and have added environmental benefits.

This research investigates the behavior of urban solid waste under possible gasification environments defined by temperature, pressure, and reactive environment. Results of this project can be used to inform participants in the urban solid waste to sustainable aviation fuel value chain, fuel suppliers, technology providers, gasification system operators, and research and development funding agencies. Project success will support the production, adoption, and use of sustainable bio-based aviation fuel – a much needed alternative to petroleum legacy fuels.

BACKGROUND: Feedstocks for SAF production include fiber, sugar, starch, and oil available from the forestry and agricultural sectors, and from urban solid wastes (USW). The fiber fraction of USW can be used to feed any of the downstream technology pathways leading to SAF products. EPA data shows that more than 100 million tons of combustible material are landfilled in the U.S. annually[1]. An estimation also reported that ~8.5 billion tons of waste materials could be mined from the existing U.S. landfills[2].

Although the use of USW for SAF feedstock shows high potential, it is not without challenges. USW may include municipal solid waste (MSW) and construction and demolition waste (CDW) that are heterogeneous in composition. A recent sampling program at a CDW landfill in Nānākuli, Hawaiʻi showed that CDW samples may contain ash approaching 10 wt% of fuel and ~25 elements of interest. In comparison, the ash in clean wood accounts for less than 1 wt% of fuel and contains ~12 elements of interest.

Gasification and gas cleanup of urban solid waste can be modeled as a series of thermochemical and phase equilibria steps defined by the thermodynamic state points of unit operations. Results can identify opportunities to improve gasification system performance by 1) managing urban solid waste components entering the gasification process, 2) guiding selection of reactor materials, and 3) avoiding operating conditions that result in ash deformation or pollutant formation. Under gasification conditions, ash present in the fuel may deform to produce vapors or liquid slags. The latter causes operating difficulties in the reactor, agglomerating bed material, and reducing fluid bed performance. The former may deposit on heat exchange surfaces, deactivate downstream catalysts, or contribute to pollutant formation. Understanding the behavior of ash elements under gasification conditions can provide information to further reactor design, process optimization, and strategies to mitigate the negative impacts of ash elements.

PROJECT STATUS/RESULTS: A literature review was conducted to identify the typical ranges for the elemental compositions of available waste-based fuels.

A sampling and characterization campaign determined the detailed composition of CDW materials mined from the PVT Land Company landfill over a period of time[3]. These data were used as input to FactSage for thermochemical equilibrium calculations to investigate:

- The fate of ash from CDW fuels under gasification at different temperatures, pressures, and in different reactive environments (oxygen, steam, and oxygen-steam);
- Possible interaction between ash elements and common fluidized bed materials or oxygen carriers in chemical looping systems;
- Possible interaction and/or deactivation of ash element and common catalysts; and

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[1] EPA. (2022) National overview: Facts and figures on materials, wastes and recycling. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.

[2] Powell, J.T., J.C. Pons, and M. Chertow (2016) Waste Informatics: Establishing characteristics of contemporary U.S. landfill quantities and practices. *Environmental Science & Technology* 50, pp 10877-10884.

[3] Bach Q-V, Fu J, and Turn S (2021) Construction and Demolition Waste-Derived Feedstock: Fuel Characterization of a Potential Resource for Sustainable Aviation Fuels Production. *Frontiers in Energy Research* 9:711808.

- Strategies to control and/or remove gas phase inorganic species (e.g. As) from product gas using sorbents.

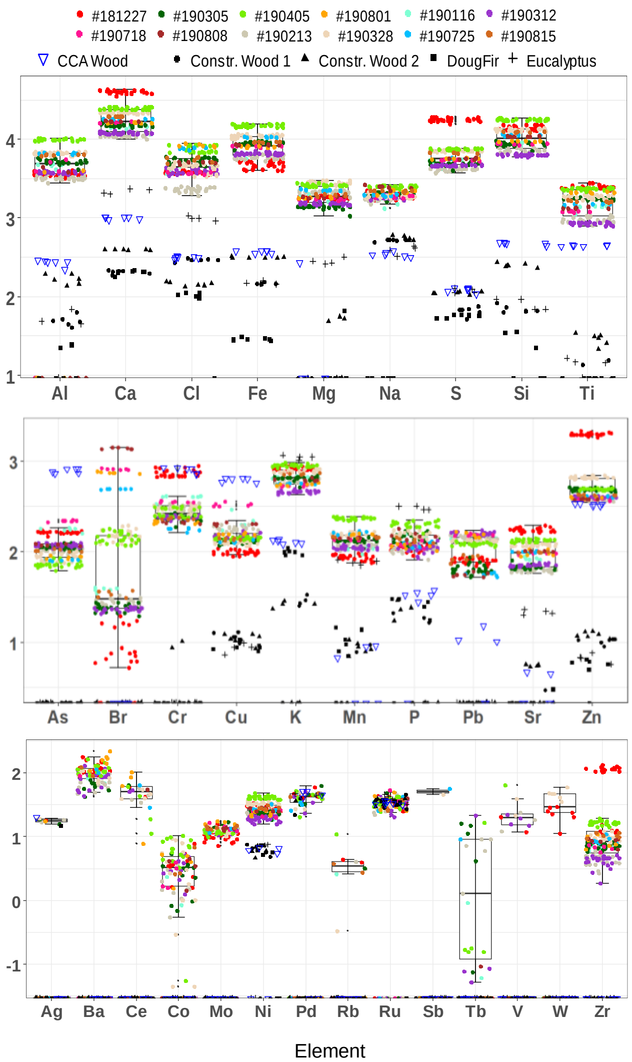

Figure 1. Element concentrations (log10 of ppm) in 12 CDW samples and five reference material samples.

The project was completed in 2023 and the significant findings and outcomes include:

- Establishing a database for fuel properties of waste-based feedstock.
- The available data revealed that fuel property values of waste-based feedstocks varied widely, indicating the importance of site specific feedstock analysis in system design.
- After gasification, arsenic from waste-based feedstocks was present in the gas phase at different levels depending on the use of gasification agents and bed materials. For example, when feedstock was gasified under oxygen, steam, and steam + oxygen conditions, 23 to 34% of the arsenic present in the feedstock was predicted to partition to the gas phase product stream. These values were reduced to 12% if bed material was included in the equilibrium gasification process calculations.
- Olivine bed material can help capture a portion of arsenic during the gasification process due to the presence of nickel in its chemical composition.
- Left unmanaged, arsenic species in the product gas stream are predicted to contribute to deactivation of Fe and Co based FT catalysts in downstream processes.
- It is possible to remove arsenic compounds by cooling hot product gas, however, cooling may also result in the condensation of high molecular weight compounds (tar).
- Copper and nickel can be employed as arsenic sorbents with sorptive capacity directly linked to the metal mass.

The study employed equilibrium calculations to analyze gasification and subsequent downstream processes. It is worth noting that real gasification systems are dynamic and considerably more complex to simulate. Experimental validation of these processes is thus recommended for further study.

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