Chair of Energy Systems
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Investigation of the Release Behavior of Heavy Metals during Gasification of Contaminated Biomass

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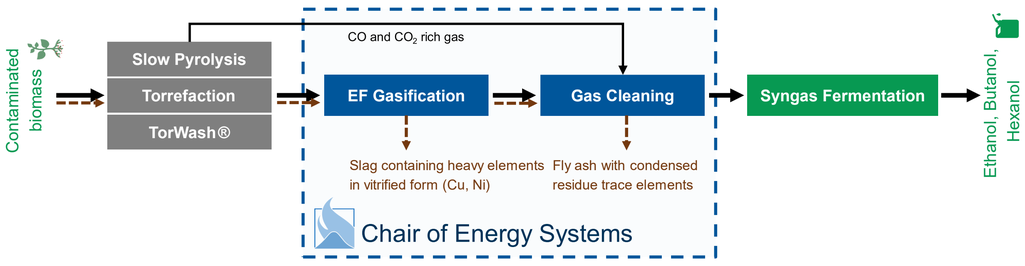
Motivation

The GOLD project at the Chair of Energy Systems aims to combine the two targets of recovering contaminated land for agricultural use by phytoremediation and producing clean and sustainable biofuels with little indirect land use change (low ILUC) in a Biomass-to-Liquid (BtL) process.



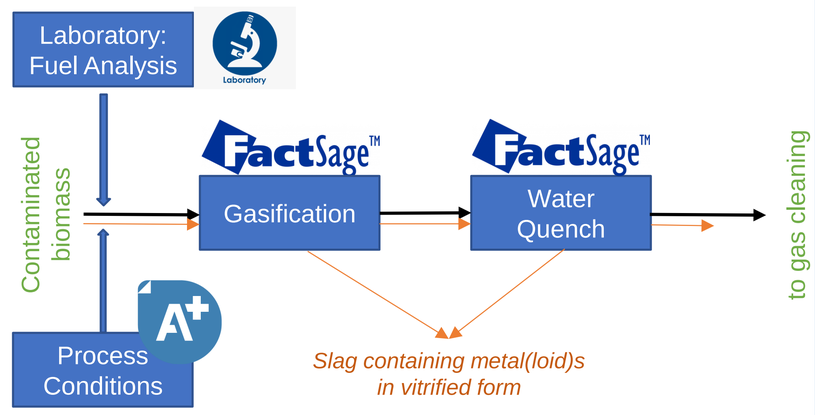
The aim of this work is to predict the fate of the heavy metal and metalloid contaminants during entrained-flow gasification. This enables an assessment to where in the process chain heavy metals and metalloids can be separated from the biomass.

Model & Methodology

The release behavior of the heavy metal and metalloid contaminants is simulated using global equilibrium analysis in FactSage. All reactions are assumed to have reached equilibrium due to the high temperatures in the gasification chamber.

The phase transition from the gas phase to the solid phase during the water quench is simulated using Scheil-Gulliver Cooling.

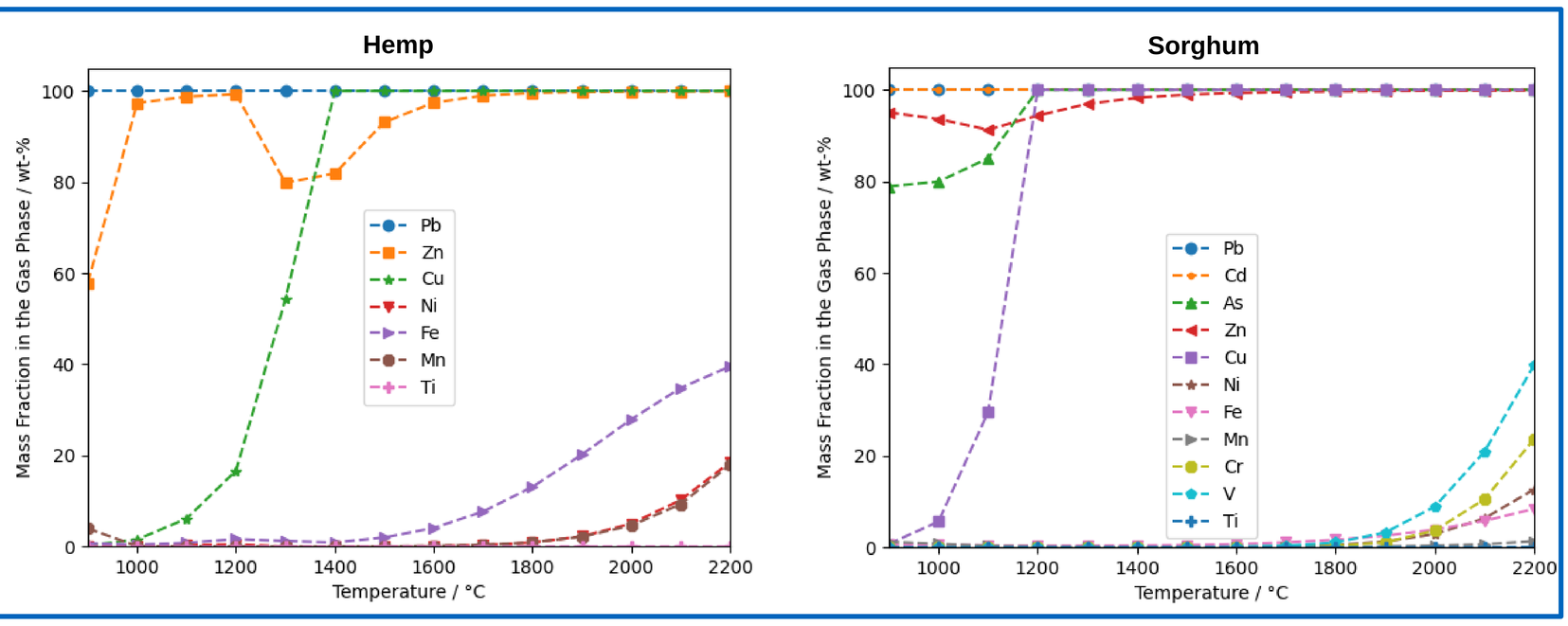
The input parameters for the model are determined in the fuel analysis in a laboratory. An Aspen Plus model is used to determine the operating parameters.



Gasification Results

The release behavior of heavy metals and metalloids of two contaminated biomasses is modelled in FactSage for entrained-flow gasification conditions:

- The volatile elements Pb, Cd, As, Zn, Cu are entirely volatilized at entrained-flow gasification conditions.
- Zn forms a slag phase in the region of ca. 1200°C.
- Ni, Fe, Mn, Cr, V, Ti are non-volatile and no substantial amount is volatilized in entrained-flow gasification conditions.

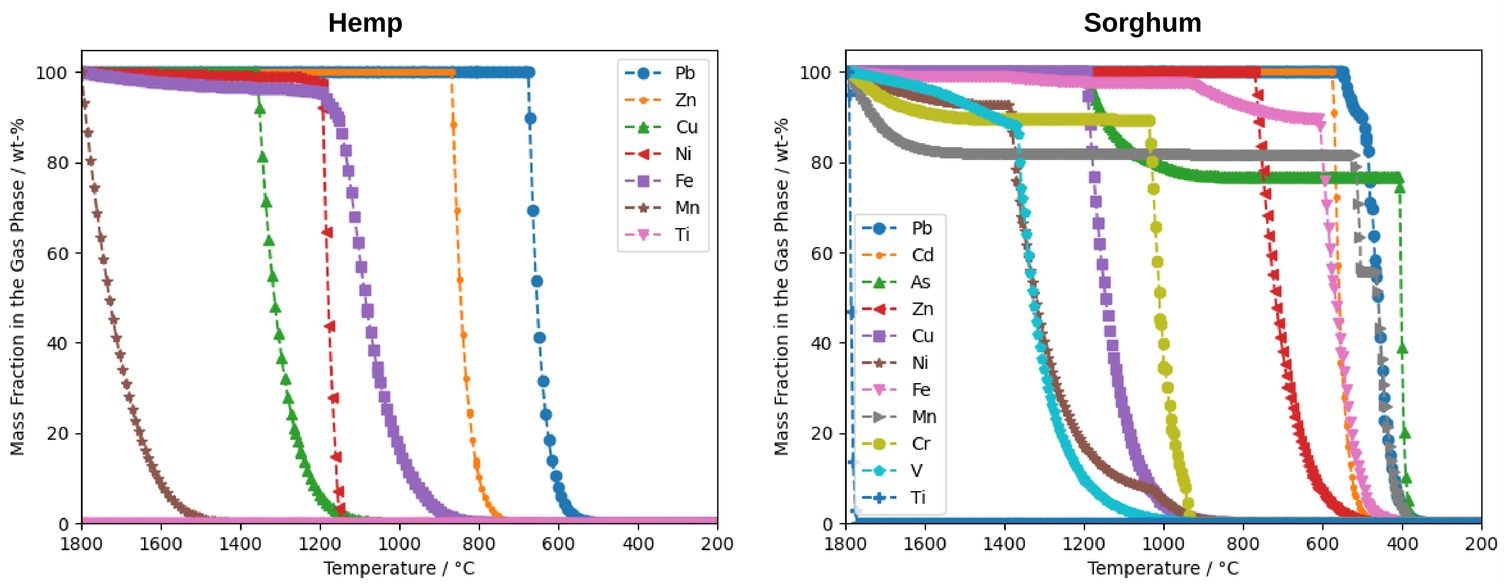


Release behavior of heavy metals and metalloids during entrained-flow gasification of contaminated hemp (left) and sorghum (right)

Quench Results

The phase transition of the heavy metals contained in the gas phase after the reaction zone and during the water quench is modelled in FactSage:

- Non-volatile elements, which are present only in small quantities in the gas phase, solidify at temperatures above 900°C.
- All volatile elements are entirely solidified in the water quench as well. No substantial amount of heavy metals and metalloids is left in the gas phase at the quench outlet temperature of 200°C.
- The formation of metal complexes and slag phases delays the solidification, leading to plateaus in the diagram. This is observed especially for the more severely contaminated sorghum.



Phase transition behavior of heavy metals and metalloids from gaseous to solid after the reaction zone of contaminated hemp (left) and sorghum (right)

Conclusion & Outlook

- A valid FactSage model is developed for the simulation of the phase transition behavior of heavy metals and metalloids during gasification.
- Pb, Cd, As, Zn, Cu are entirely volatilized in entrained-flow gasification conditions.
- Ni, Fe, Mn, Cr, V, Ti are not substantially volatilized.
- Non-volatile and semi-volatile elements start to recondense in the gasification chamber.
- All metals are solidified in the water quench.
- The release and solidification behavior heavily depends on the feedstock composition and operating conditions.

- More contaminated biomasses are analyzed in order to identify more trends and correlations.
- Experimental studies are performed in order to validate the simulation results.

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