Control of Emissions from Combustion of Cesium-Contaminated Biomass via Sorbent Injection

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Presentation at 2019 EPA International Decontamination Research and Development Conference; Norfolk, VA; November 19-21, 2019

Outline

- Radiological Dispersal Device (RDD) Scenario
- Fukushima Biomass Statistics
- Behavior of Cs in Incinerators
- Goals of This Study
- Experimental Approach
- Results
- Conclusions
- Next Steps

RDD Scenario

Fukushima Biomass (Estimated)

Category of Land use	Combustible Material (million m^3)
Housing, Facilities, etc	0.38 – 0.47
Rice Fields	1.3 – 1.7
Other Fields	
Pasture, Orchards, etc	
Forest	1.6 – 5.4
Other	0.1
Total	3.3 – 7.7

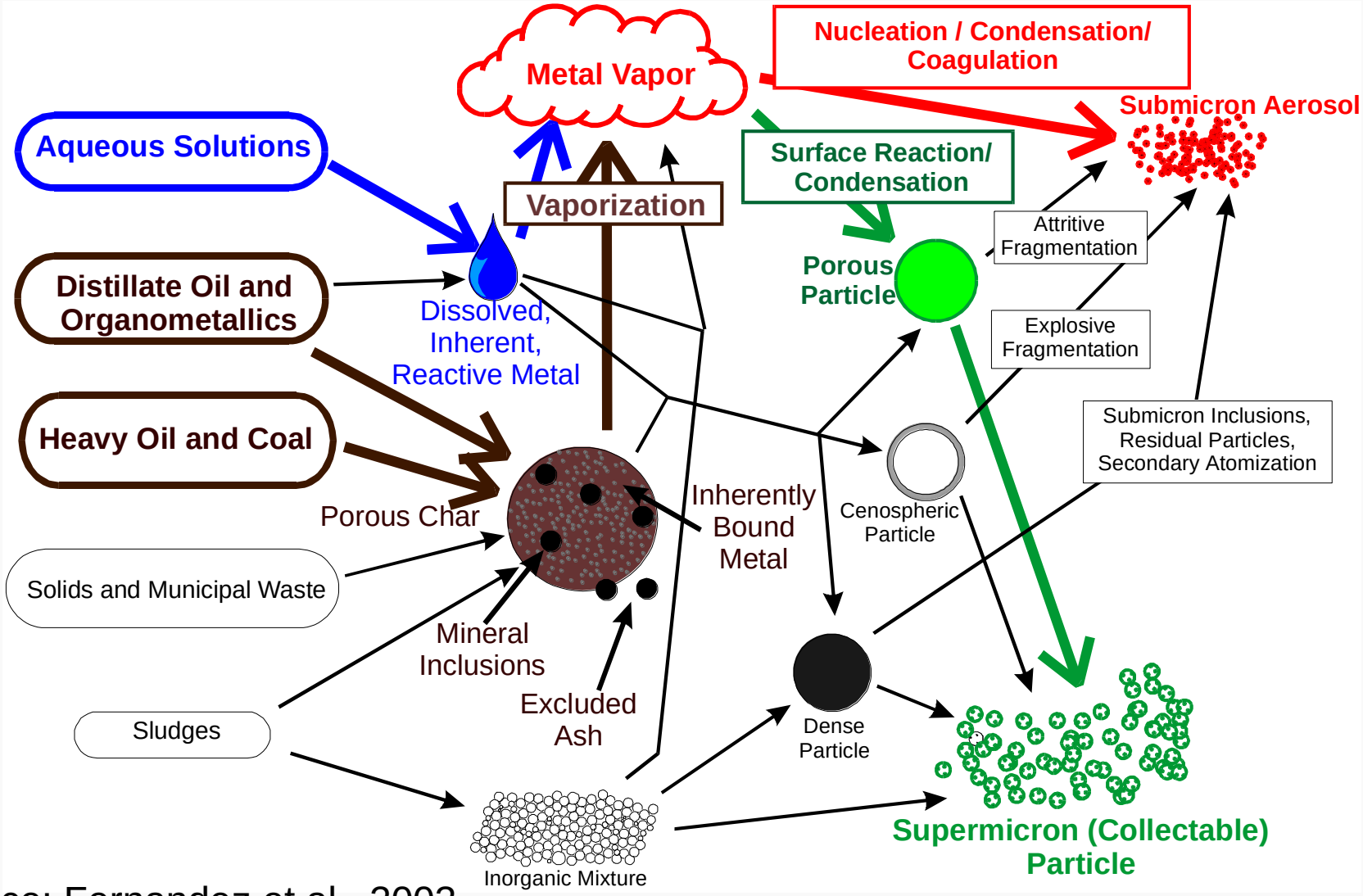
Note: Hurricane Katrina produced approximately 75 million m^3 of debris, much of which was combustible

Interim Storage Facility Safety Review Committee Report:
http://josen.env.go.jp/area/processing/pdf/safety_measure_02.pdf

Behavior of Cs in Incinerators

- Cs as an alkali metal, behaves similarly to Na and K
- Vaporizes readily within combustion environment
- Nucleates and condenses downstream into ultrafine particulate matter (PM)
- Submicron aerosol $d_p \approx 100 – 200$ nm

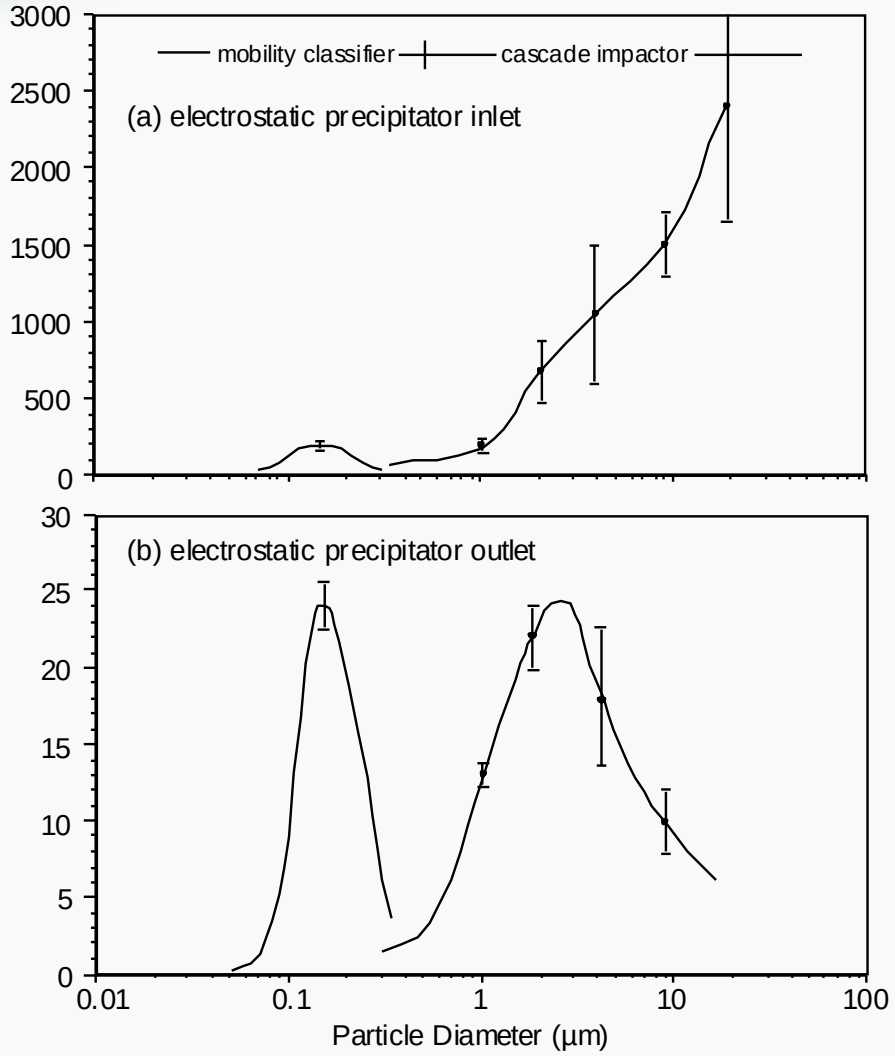
Metal Transformation Mechanisms



Source: Fernandez et al., 2003

Electrostatic Precipitator (ESP) PM Partitioning

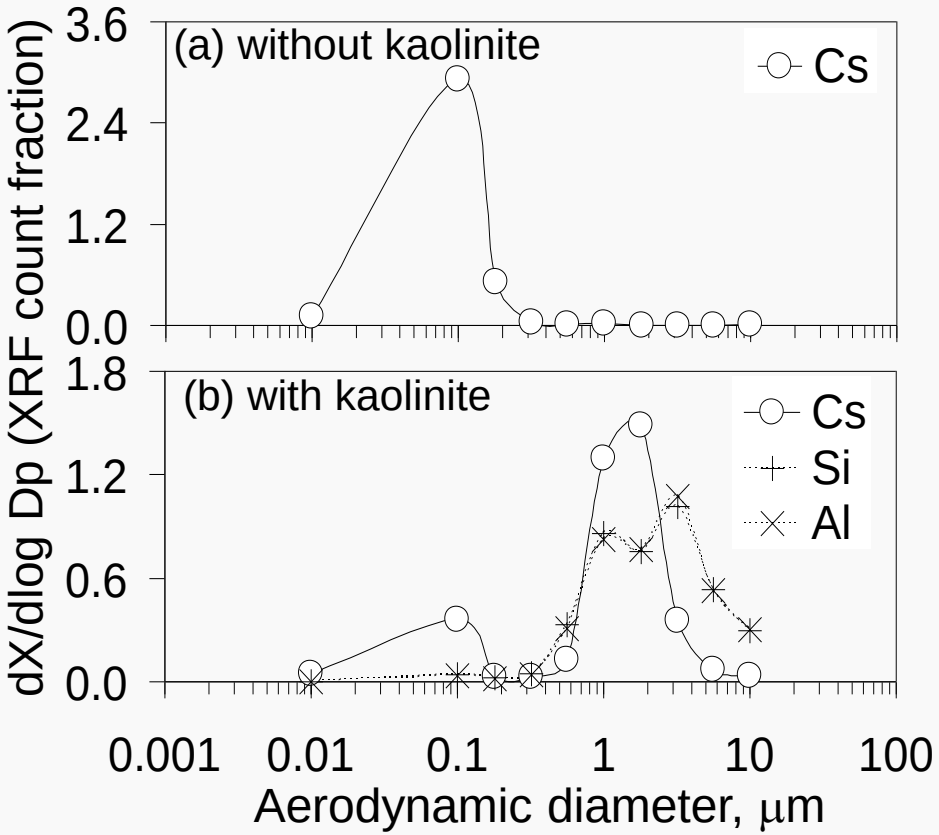
- Control technologies remove large PM preferentially
  - >99% 10 µm
  - <90% 0.2 µm
- Large fraction of emissions composed of accumulation mode aerosol
- Enriched in volatile and semi-volatile metals



Markowski et al., 1980

Past Results (Yoo et. al)

- Cs-doped natural gas flame
- Injection of kaolinite sorbent at point in furnace where T ≈ 1400-1500 K
- Up to 80% capture of Cs on sorbent particles (d_p ≈ 2 – 10 μm)



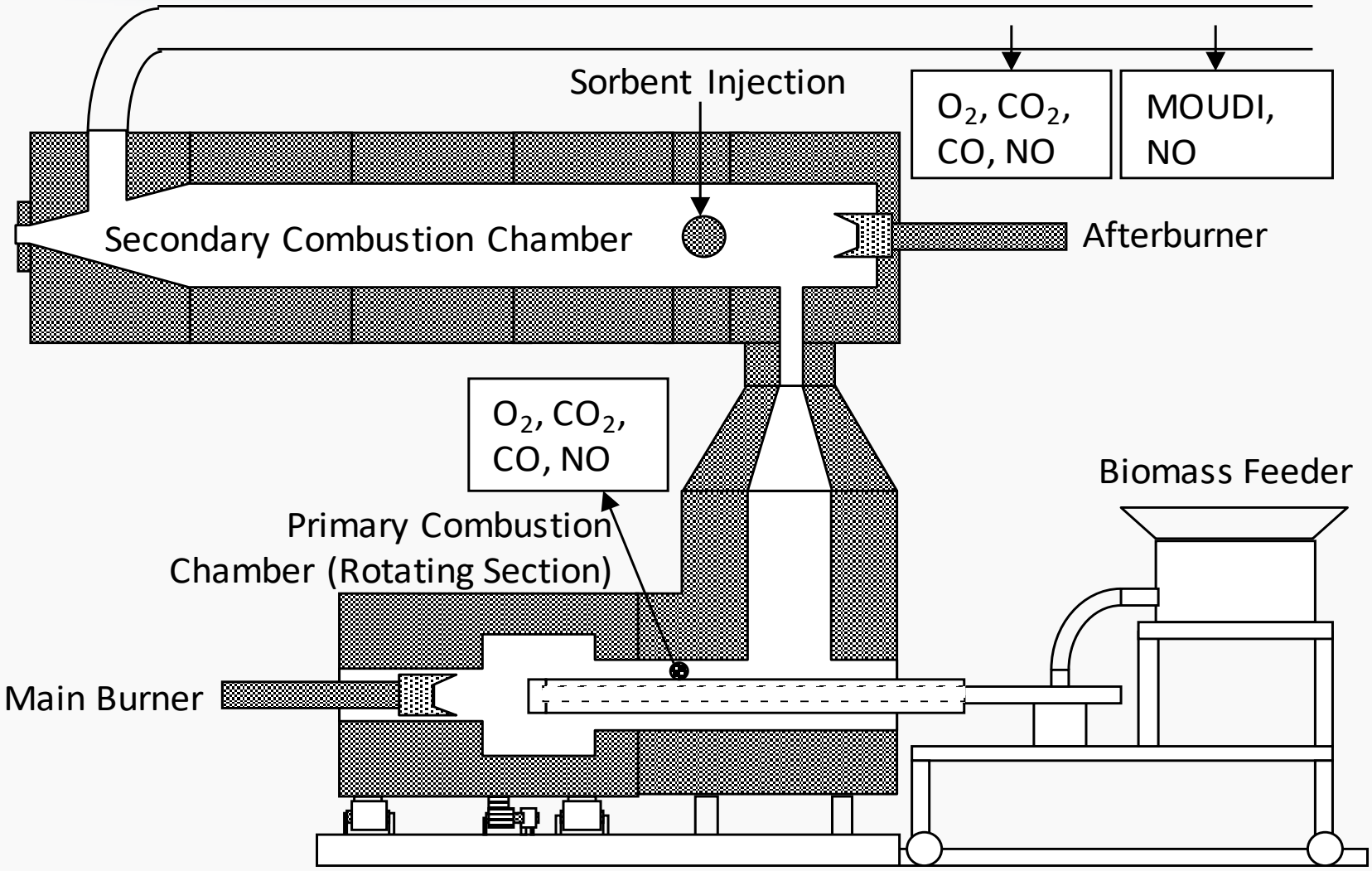
Goals of This Study

- Examine biomass-bound Cs behavior and transformations in incinerator environment
- Determine whether alumina silicate sorbent injection could shift Cs into supermicron particle fraction in a mass-burn biomass combustion system
  - Potential competition for active sorbent sites between Cs, K, and Na
  - K and Na present in concentrations >> Cs

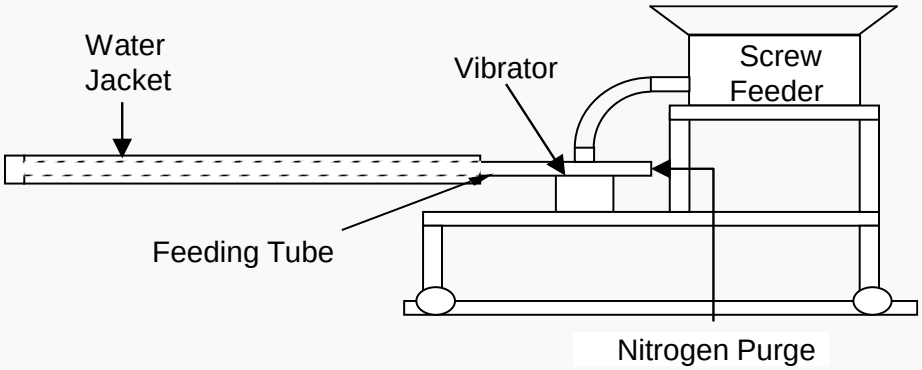
Experimental Approach

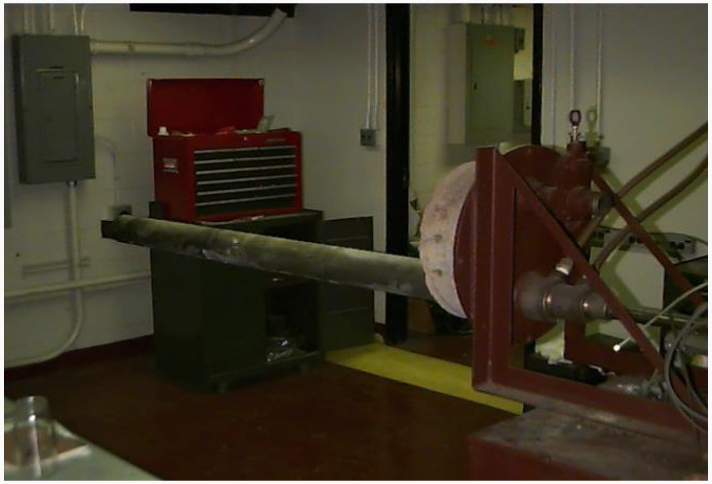
- Rotary Kiln Incinerator Simulator
- Co-firing natural gas + biomass
  - Biomass pellets
  - Doped with CsCl
- Reproduce optimal temperature profile from Yoo et. al (1246 K)
- Micro-Orifice Uniform Deposition Impactors™ (MOUDI) impactor sampling to determine particle size distribution
- ICP-MS analysis of MOUDI plates to determine partitioning of Cs between particle size fractions

Rotary Kiln Incinerator Simulator



Biomass Feeder





- Screw feeder to drop biomass pellets into tube with slight incline
- Vibrator to move pellets down length of tube
- Pellets drop into center of rotating kiln section

Biomass Composition

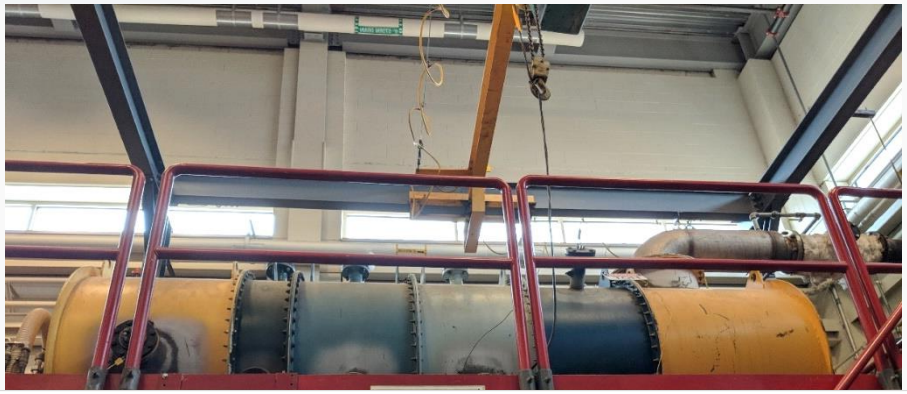
Measurement	Value
Carbon	45.95%
Hydrogen	6.18%
Nitrogen	< 0.5%
Oxygen	42.71%
Chlorine	20 ppm
Sulfur	0.042%
Fixed Carbon	12.62%
Weight Loss on Drying	6.00%
Volatile Matter	84.60%
Ash	1.97%
Heat of Combustion	18091 kJ/kg

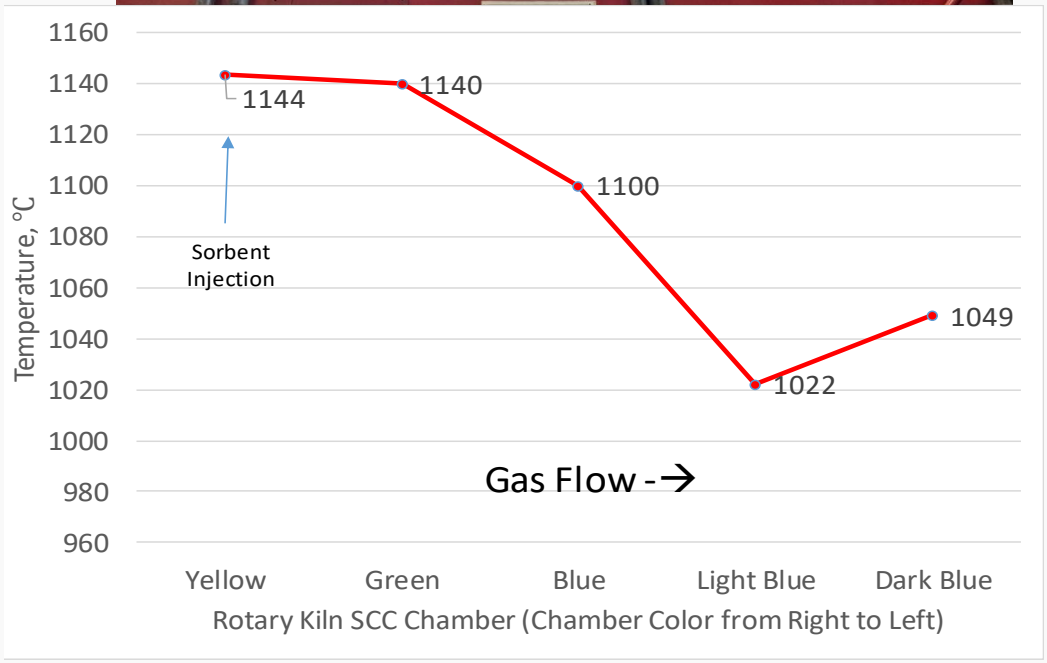
Test Matrix

Test Condition #	Cs Conc., mg/kg Biomass	Biomass Feed Rate, kg/h	Sorbent Feed Rate, g/h
1 – Natural Gas Background	NA	NA	NA
2 – Biomass	NA	3.6	NA
3 – Biomass + Sorbent	NA	3.6	33.3
4 – Natural Gas Background	NA	NA	NA
5 – Biomass + Cs	68.2	3.6	NA
6 – Biomass + Cs + Sorbent	68.2	3.6	33.3

NA – Not Applicable

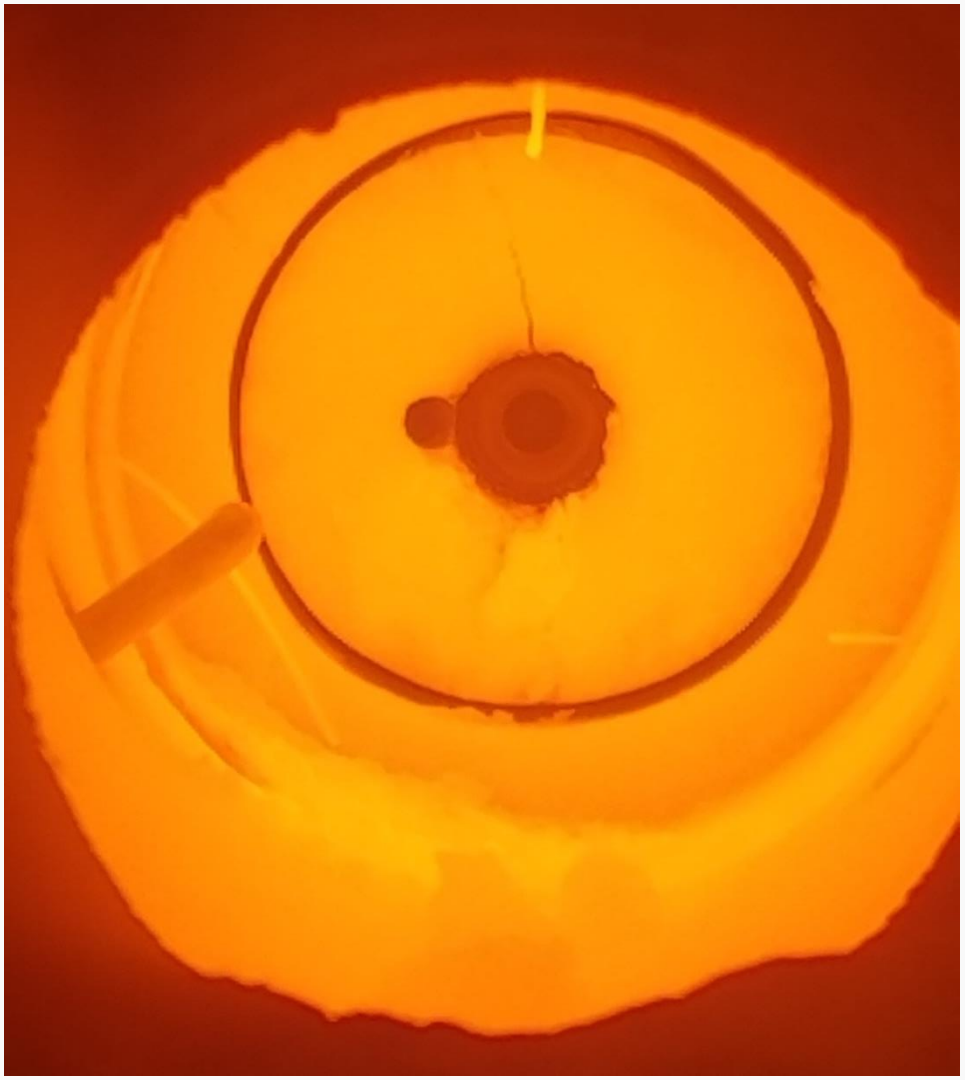
Temperature Profile





RKIS Secondary Combustion Chamber

Afterburner View with Injector



Sampling Setup

Sorbent Feeder

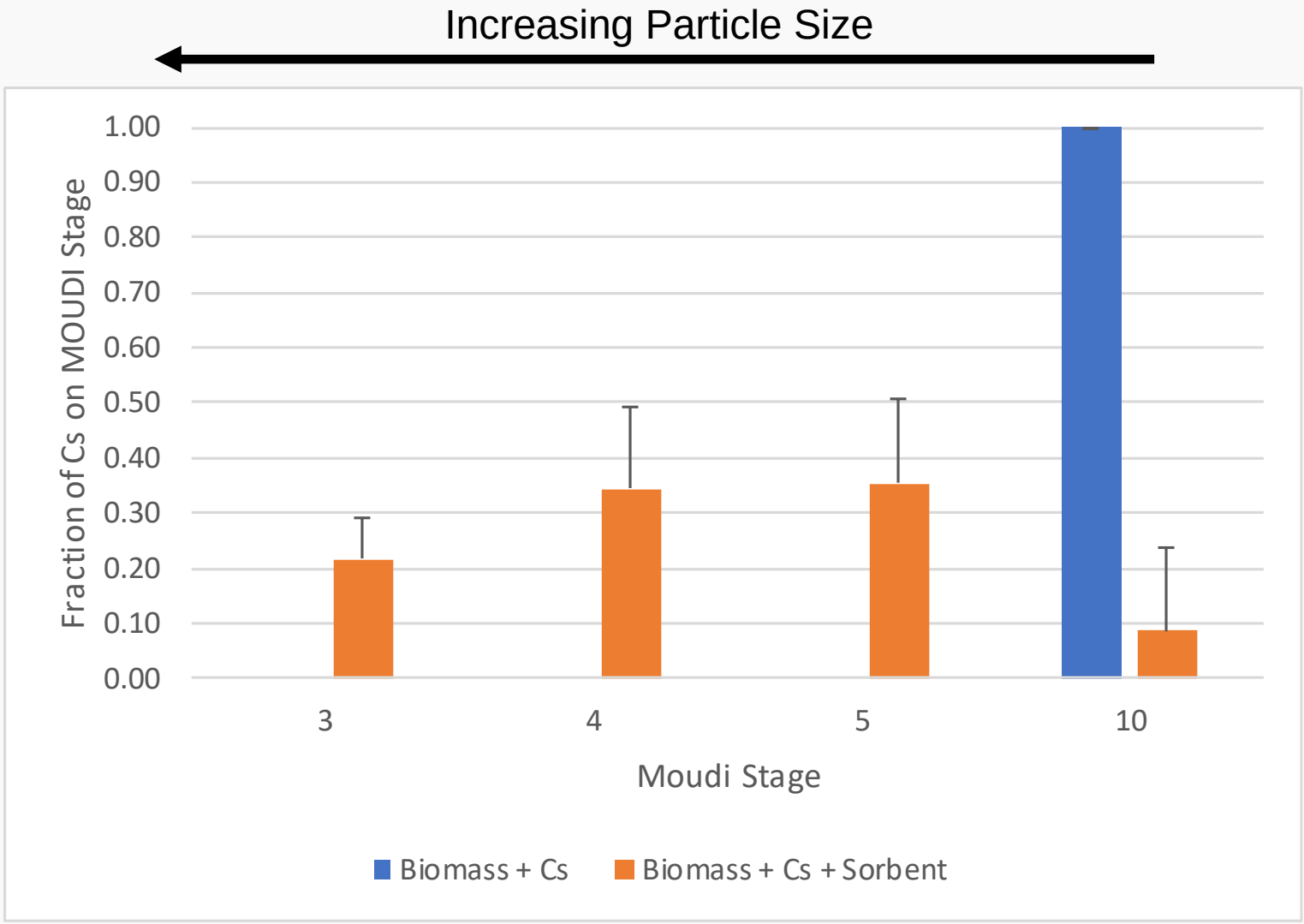
Particle Sizes on MOUDI Stages

Stage	Dp Min (µm)	Dp Max (µm)
10 (after-filter)	0.01	0.18
8	0.18	0.32
7	0.32	0.56
6	0.56	1
5	1	1.8
4	1.8	3.2
3	3.2	5.6
2	5.6	10
1	10	15.7
0 (Inlet)	15.7	>15.7

Red highlighted stages are ones that Cs was found in following sampling

Sorbent mean size approximately 2.5 µm

Cs Particle Partitioning



Conclusions

- With sorbent addition, Cs was successfully shifted towards the larger particle sizes associated with the sorbent
- Estimated 91% of Cs Captured On Sorbent (based on fraction of Cs moved to the > 1µm size cut)
  - Comparable capture to what was shown in natural gas system
  - Better performance than in vertical tunnel combustor with powderized biomass
    - Corncob flour 65% capture
    - Pine flour 41%-88% capture
- Suggests that kaolinite sorbent injection may be a useful combustion modification that could be used in practical-scale combustion systems while burning Cs-contaminated biomass, especially in systems with fabric filters

Next Steps

- Evaluate the effect of the presence of biomass Cl, Na, K to assess the viability of this process on a variety of different biomass materials
- Assess the Cs solubility and leachability once captured on the sorbent

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