Biochar Carbon Sequestration

A study on the effect of particle size and feedstock on physical and chemical stability of biochar

Meghana Rao
Jesuit High School
Portland, Oregon

Why is carbon sequestration important?

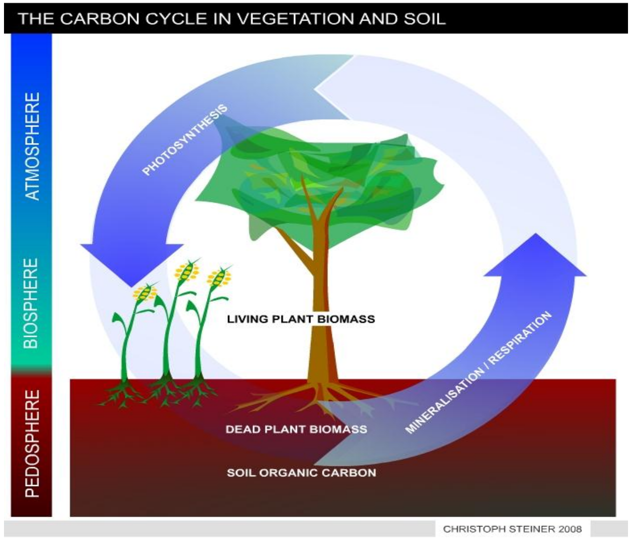
- Current atmospheric CO_2 level: 393.03ppm
  - Increasing at an accelerating rate
  - Safe level upper bound: 350ppm

- Emissions are increasing global warming and causing irreversible changes

- Carbon sequestration:
  - The process of removing carbon from the atmosphere and depositing it in a reservoir

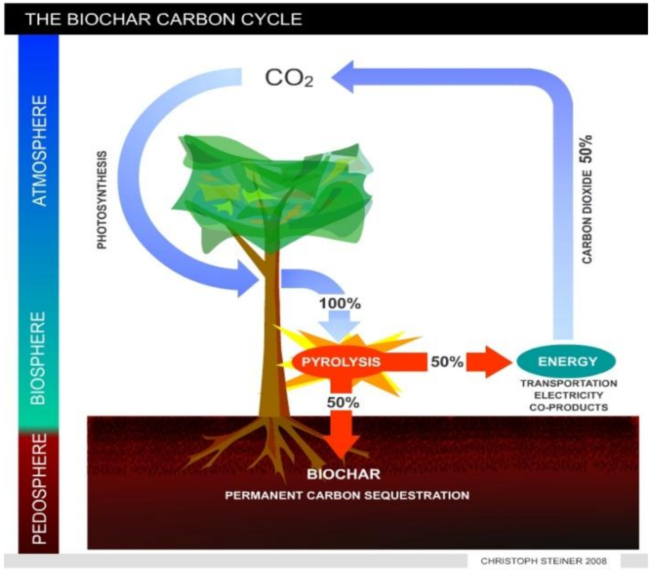
Biochar Carbon Sequestration

- Sequesters ~50% of the carbon dioxide taken in by original feedstock
- Half-life ranges from hundreds to thousands of years
- **Stability** determines how long the carbon will be sequestered by the biochar
- Need to determine which chars are most stable to optimize carbon sequestration abilities



THE CARBON CYCLE IN VEGETATION AND SOIL

CHRISTOPH STEINER 2008



THE BIOCHAR CARBON CYCLE

CHRISTOPH STEINER 2008

Problem Statement

- **Currently, there is no protocol to assess the stability of biochar**
  - Limits understanding of what properties affect longevity in the soil
- **Properties of biochar vary based on feedstock /pyrolysis temperature**
  - Current evaluations are time-consuming (incubation)
  - Requires time-efficient method of assessing stability
- **The effect of biochar particle size on longevity is unknown**
  - Controllable factor
  - Could be used to optimize carbon sequestration benefits

Objective and Hypotheses

Objective

To determine the effect of

1. Particle size (63-250µm and 250-2000µm)
2. Feedstock (hazelnut shell and Douglas fir wood)

on the relative stability of biochar

Hypotheses

1. Char of 250-2000µm will be more physically and chemically stable than char of 63-250µm because of the decrease in surface area.
2. Hazelnut shell biochar will demonstrate greater stability than Douglas fir biochar due to its denser structure.

Making the Biochar

- Feedstock selection
  - Hazelnut shell and Doug fir
- Production methods:
  - 1 temp from TLUD stove (360-420C)
  - 3 temps in Fluidyne Pacific Class Gasifier (370C, 500C, 620C)
  - Comparison of stability of char made with more refined technology compared to stoves for rural areas.

Top-Lit Updraft (TLUD) stove

Fluidyne Pacific Class Gasifier

Variables

- Independent variables:
  - particle size
  - feedstock
  - frequency of ultrasonication
  - time period of oxidation

- Dependent variables:
  - % mass lost after oxidation
  - % total carbon lost after ultrasonication

- Constants:
  - amount of biochar used in each test
  - concentration of hydrogen peroxide used in oxidation
  - time period for drying after oxidation

Evaluating Stability of Biochar

- Definition of **stability** used:
  - A char's ability to withstand a broad variety of physical and chemical agents that occur in the surrounding environment.

- Approached from two aspects:
  - **Physical stability**
    - Replicating physical weathering through ultrasonication at increasing frequencies

  - **Chemical stability**
    - Replicating chemical weathering through long-term chemical oxidation

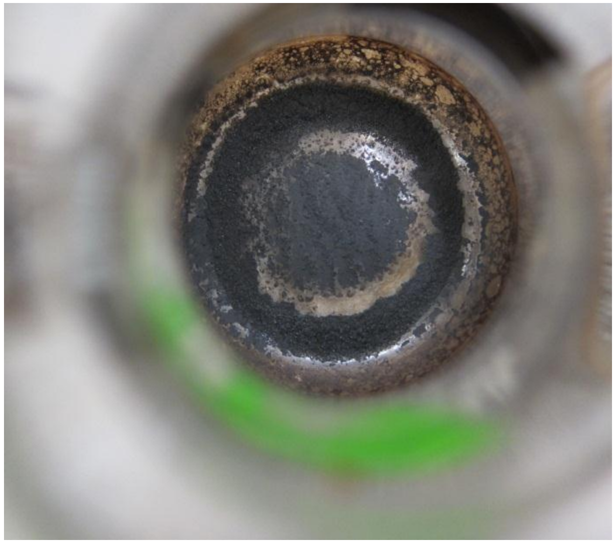
  - By applying heavy stresses to the biochar and understanding its reactivity, it allows for an understanding of how biochar degrades over long periods of time

Chemical Stability Procedure

- 1g char + 50ml (3% hydrogen peroxide) – 3 trials each
- Place samples in 75^{0}C water bath for 2, 4, and 8 hour intervals
- Dry at 105^{0}C for 24 hours and weigh
- Repeat oxidation until each sample has undergone 70 hours

Chars in water bath

Char after oxidation

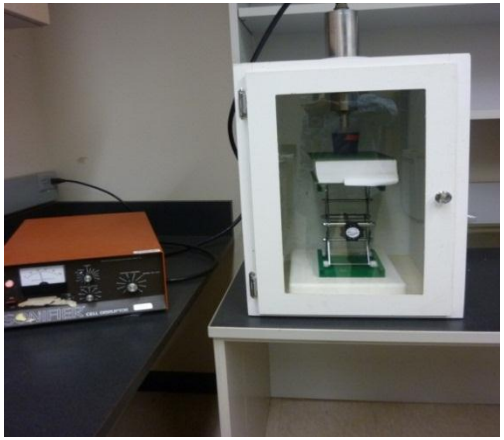


Hazelnut char after oxidation

Physical Stability Procedure

- Suspend 3g in 300ml water in a thermos cup
- Ultrasonicate for:
  - 1 min 44 sec = 60J/ml
  - 5 min 54 sec = 250J/ml
  - 13 min 41 sec = 450J/ml
  - 29 min 22 sec = 644 J/ml
- Filter samples and collect filtrate
- Use Total Organic Carbon Analyzer TOC-VC5H to determine amount of carbon leached into filtrate

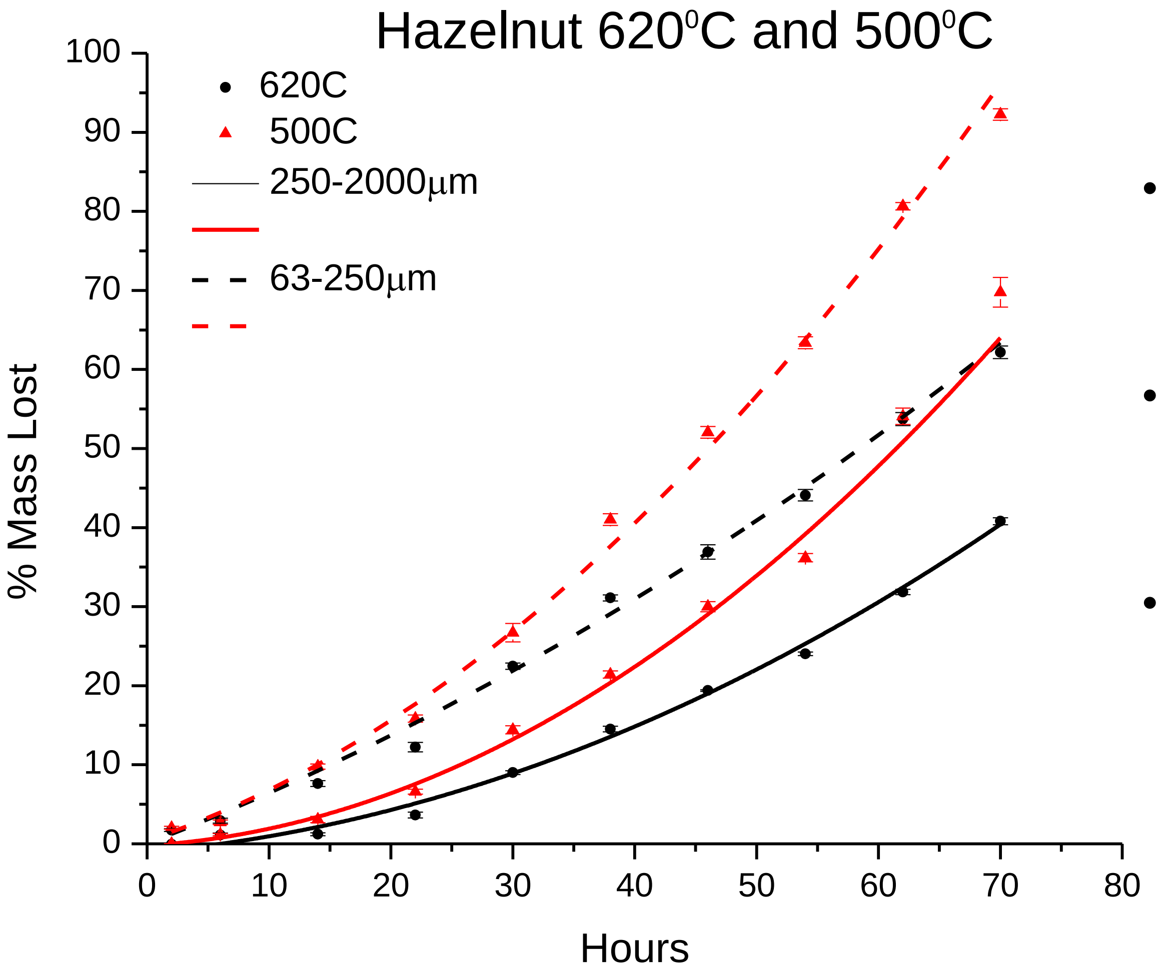
Ultrasonicator



Filtering the samples

Chemical stability results: Hazelnut 620^{0}C and 500^{0}C

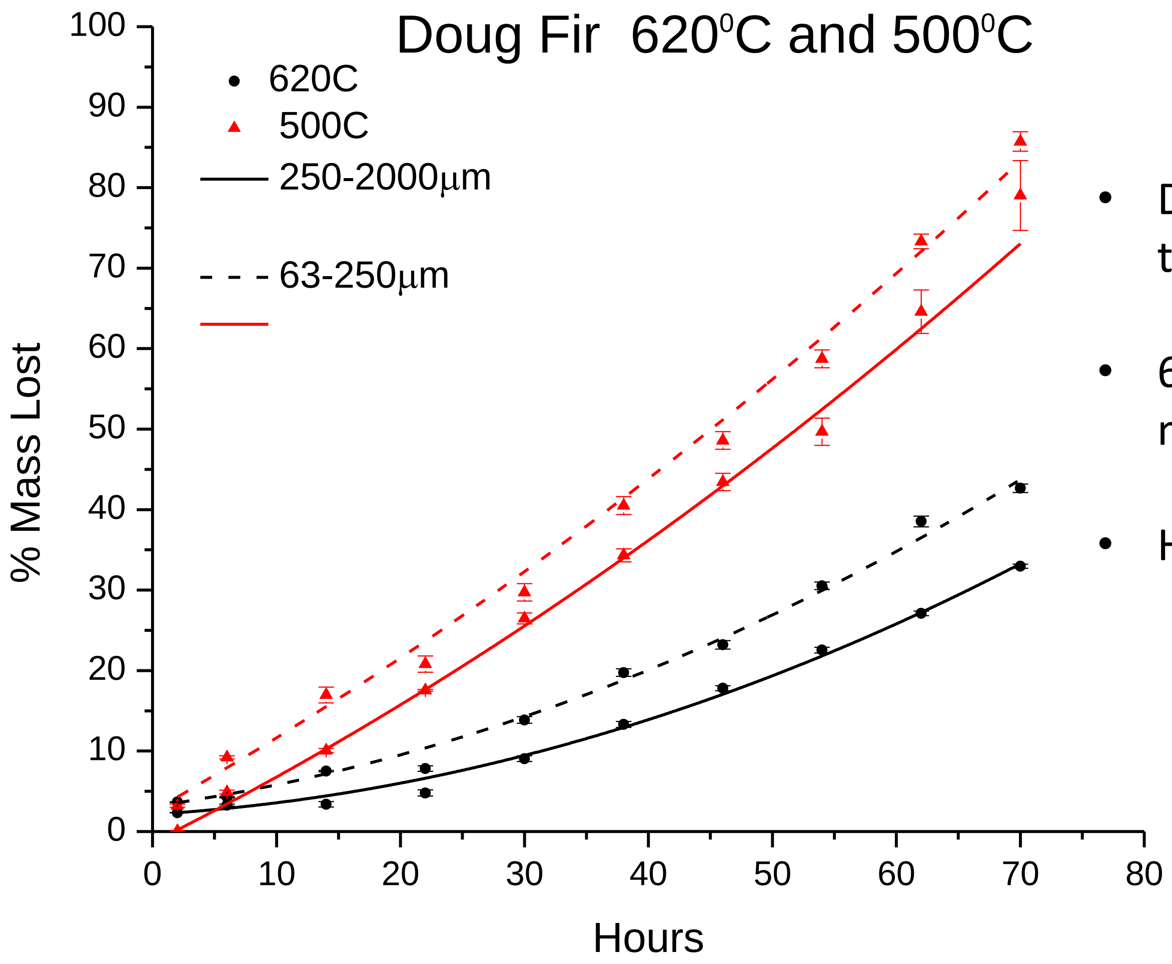
Percent Mass Lost after Chemical Oxidation



- Smaller particle char has faster rate of oxidation
- The smaller particle char lost more mass
- Higher temp (620^{0}C) char lost less mass

Chemical Stability Results: Doug Fir 620^{0}C and 500^{0}C

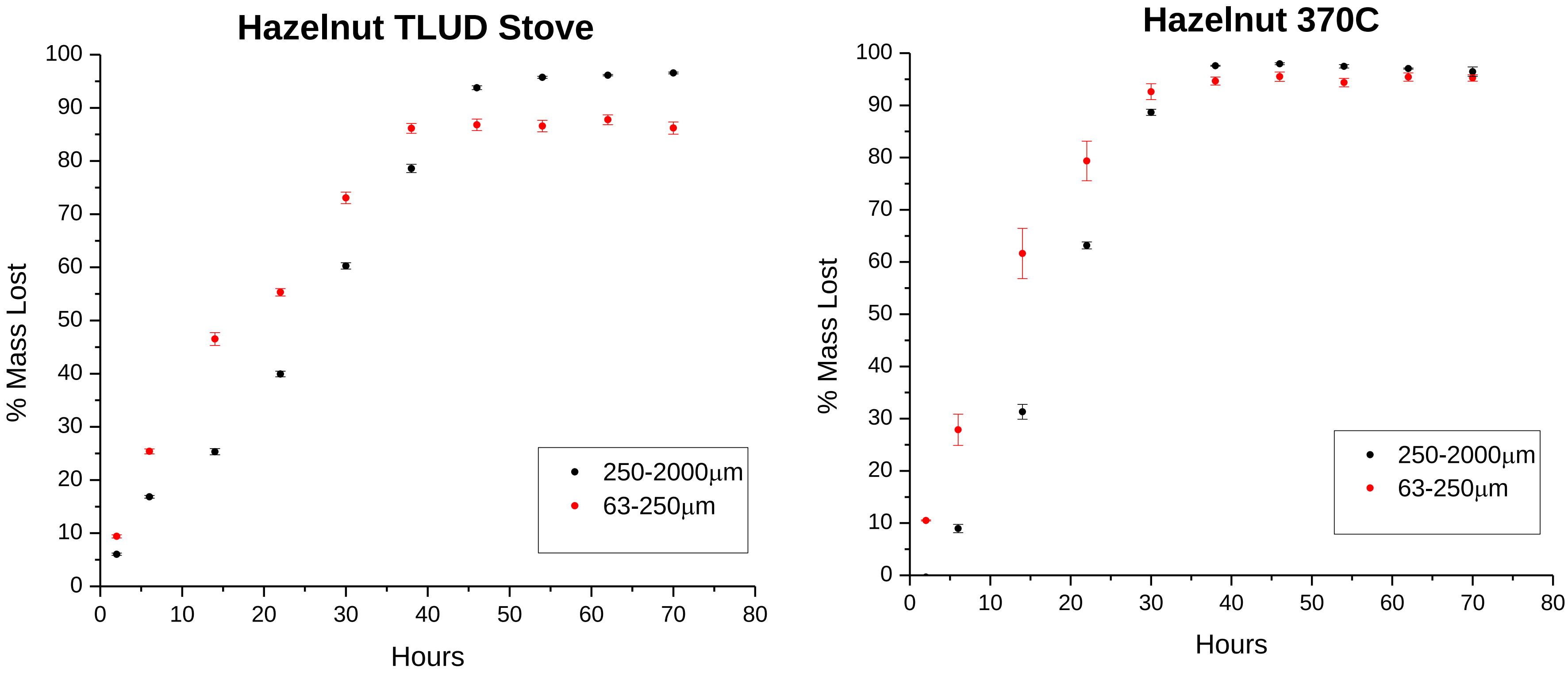
Percent Mass Lost after Chemical Oxidation



- Doug Fir 500C oxidizes 2X faster than 620C
- 63-250µm char lost 10% more mass at both temperatures
- Hydrophobic vs. hydrophilic?

Chemical stability results: Hazelnut 370^{0}C and TLUD Stove

Percent Mass Lost after Chemical Oxidation



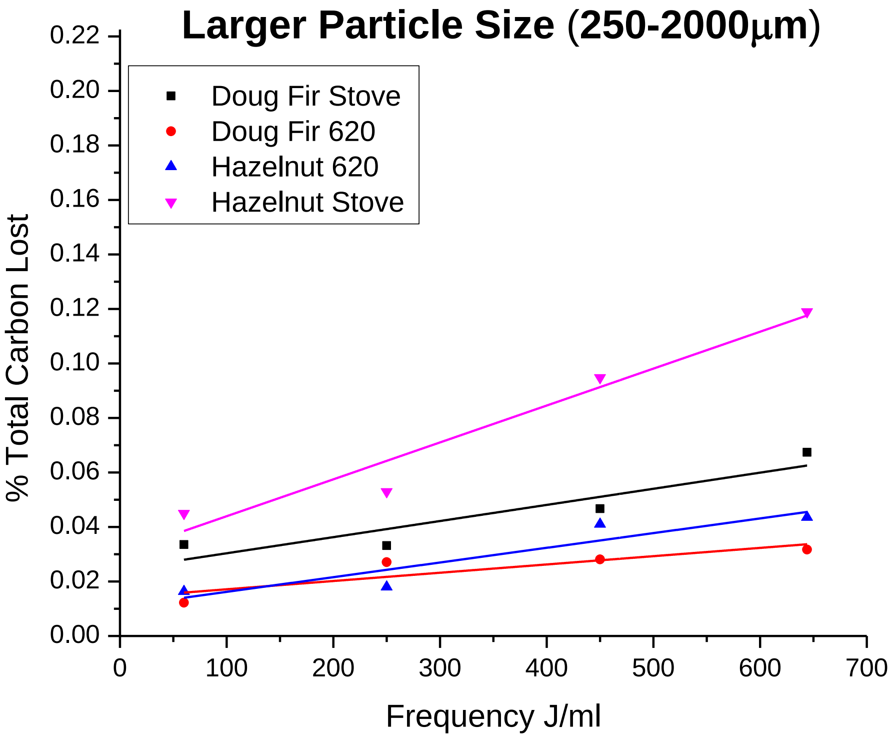
- All char samples oxidized after 30-40 hours (level off)
- **Particle size does not affect decay rate of low temperature hazelnut char**

Summary 1: Chemical Stability

- Particle Size
  - Smaller particles broke down at a faster rate than larger particles for higher temperature char
  - Particle size did not impact lower temperature chars
- Feedstock
  - Douglas fir char lost less mass than hazelnut shell char after oxidation across temperature

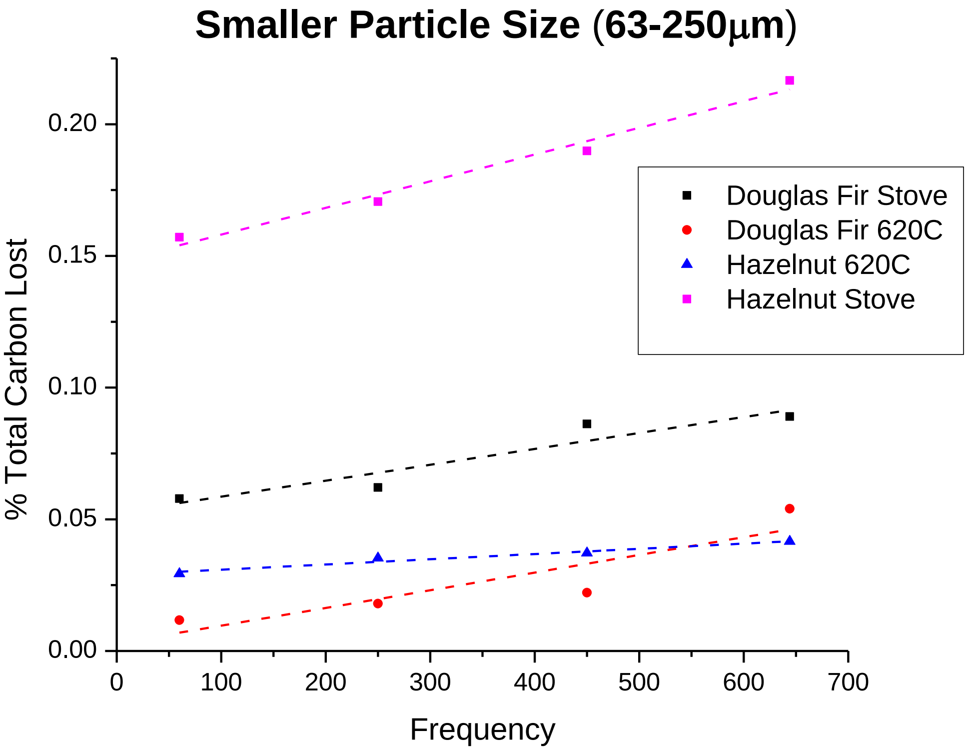
Physical Stability Results

Percent Total Carbon Lost after Ultrasonication



Larger Particle Size (250-2000µm)

- Stove char lost more carbon than 620C char for both feedstock



Smaller Particle Size (63-250µm)

- Smaller particles behaved similar to larger particles
- Mass lost doubled for hazelnut stove

Summary 2: Physical Stability

- All chars lost under 0.2% total carbon after 30 minutes of ultrasonication.

- Feedstock
  - Douglas fir char lost less total carbon after ultrasonication than hazelnut shell char

- Particle Size
  - Smaller particle chars were not significantly more susceptible to the ultrasonication

Conclusions

- Both particle size and feedstock influence char stability
  - Significant difference noticed at higher temperatures
  - Douglas fir char demonstrated greater stability than hazelnut char

- Larger particle char made at higher temperatures were more stable than smaller particle char

- Lower temperature chars were less stable, irrespective of particle size and feedstock

Applications of Research

- Ability to select biochar to optimize its longevity based on dominant environmental factors

- Ability to optimize stability based on the controllable factor of particle size – larger particle size = longer carbon sequestration benefits

Limitations

- Procedure currently determines relative stability of the chars
- The definition of stability was solely approached from two characteristics of potential importance
- Frequency output by ultrasonication is limited and inconsistent
- **Future Research**
  - Understanding of the interaction between biochar and soil organic matter on stability
  - Other applications of biochar: isolating the graphene from biochar

Acknowledgements

- Dr. Markus Kleber (Assistant Professor- Soil and Environmental Geochemistry, Oregon State University)
  - Provided laboratory and guidance on methods
- Myles Gray (Graduate student at Oregon State University)
  - Supervised laboratory work
- John Miedema (Founder - Pacific Northwest Biochar Initiative)
  - Made biochar in gasifier for the research
- Mr. Tom Miles (T.R. Miles, Technical Consultants, Inc.)
  - Mentor and advisor
- US Biochar Initiative

References

- Keiluweit, M; Nico, S.P.; Johnson, M.G.; Kleber, M. 2010. *Environ. Sci. Technol. 44,* 1247–1253.

- Zimmerman, AR. 2010. Abiotic and Microbial Oxidation of Laboratory-Produced Black Carbon. *Environ. Sci. Technol. xxx,* 000–000M.

- Lehmann, Johannes, Joseph, Stephen. Biochar for Environmental Management Science and Technology. Sterling: Earthsacan, 2009.

Thank you!