Elements on the move: the effect of weathering on wildfire produced charcoal

Hiwot Gebremedhin [ab], Amy Kingston [ab], Katherine Snihur [a], Daniel Alessi [a], Kurt Konhauser [a]
[a] Department of Earth & Atmospheric Sciences, University of Alberta
[b] WISEST Summer Student Researcher

UNIVERSITY OF ALBERTA

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Introduction

Objective: The purpose of this study is to determine the reactivity of wildfire produced charcoal and how it may adsorb and facilitate the transport of essential nutrients (elements, metals, micronutrients) from terrestrial to marine reservoirs.

- Weathering of charcoal into streams and rivers might be a major mechanism by which nutrients are transferred from land to ocean.
- Previous studies indicate Black Carbon (BC), a component in charcoal produced from forest fires modifies rates of turnover in the carbon cycle, slowing down its cycle [1]
- BC accumulates as a "global carbon sink" in marine sediments instead of being mineralized and emitted to the atmosphere as CO_2 [1,4]
- Biogeochemical cycles replenish/recycle matter and allow elements to be available for organisms to use as the nutrients move through living and nonliving reservoirs.[3]
- Forest fires may indirectly influence the natural biogeochemical cycling of elements by sequestering these nutrients as an sink, trapping nutrients in one reservoir, preventing the cycle to continue, causing nutrients to become unavailable for future organisms use[1]
- This study investigates the adsorption potential of charcoal and its ability to bind to and transport similar ions to cadmium, to determine its likelihood to have an effect on vital nutrient transport patterns in the natural environment

Figure 1A (top) and **Figure 1B** (bottom)

Figure 01: the scenery (Fig. 1A) and the forest floor (Fig. 1B) of the field sites a year post an active wildfire in Mount Hunter, British Columbia.

Methods

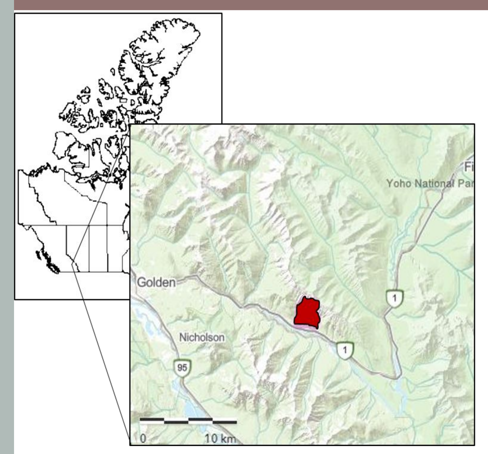

Figure 02: the location of the field sites in Mount Hunter, British Columbia on a map

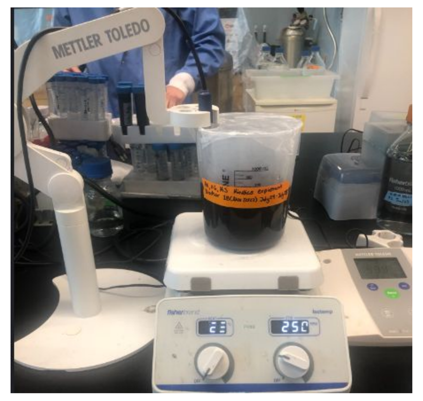

Figure 03: depicts the kinetics experiment for the 1B sample - adjusting the pH back to 6 with a pH probe and 1 M HNO_3

- Samples of charcoal residue were collected on November 4th, 2021 and on November 3rd, 2022 Mount Hunter, British Columbia 12 days and a year after an active wildfire
- Samples were measured for total CHNS using a Perkin Elmer 2400 series II CHNSO Analyzer with a combustion and reduction temperature of 975 and 500 degrees celsius respectively
- The concentration of O was determined by subtraction of all CHNS.
- Conducted series of kinetic experiments for three sets of charcoal samples creating an aqueous environment under a controlled pH of 6 (river-like conditions) with 600mL stock solution 0.01M NaCl, and 0.6 grams of pyrogenic carbon, sampling 5mL at certain time stamps prior and after adding 1 ppm Cd^{2+}
- Use an ICP - MS (Inductively Coupled Plasma Mass Spectrometry) instrument to determine the percentage of cadmium cation adsorption to the reactive sites (functional groups) of the surface of charcoal overtime.

Results

Figure 04: Kinetics Graphs - ICP-MS

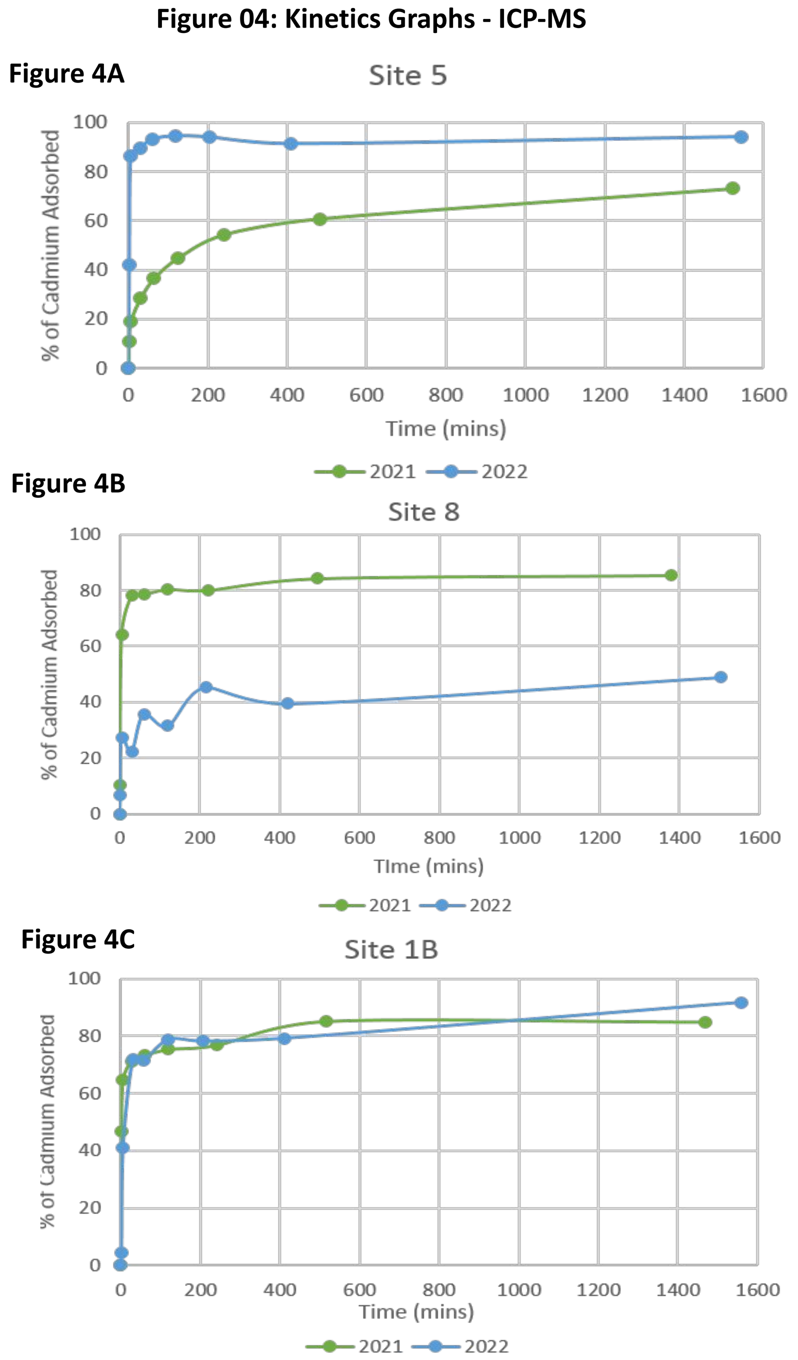

Figure 04: a comparison of the trends of adsorption of Cd^{2+} between each of the 2021 and 2022 samples of charcoal in their respective field sites overtime.

Figure 4A: shows the percentage of Cd^{2+} binding to the reactive surface of charcoal overtime has **increased** with the 2022 samples compared to the 2021 samples from site 5.

Figure 4B: shows the percentage of Cd^{2+} binding to the reactive surface of charcoal overtime has **decreased** with the 2022 samples compared to the 2021 samples from site 8. The 2021 sample stabilized at around 500 minutes at about 85%.

Figure 4C: shows the patterns of the 2021 and 2022 charcoal to adsorption of Cd^{2+} are **nearly identical** despite minor differences, and both adsorption abilities are quite efficient.

Figure 05: compares the average percentage of CHNSO composition of the charcoal from their respective field sites in 2021 to 2022.

Figure 05: Composition - Perkin Elmer Graphs

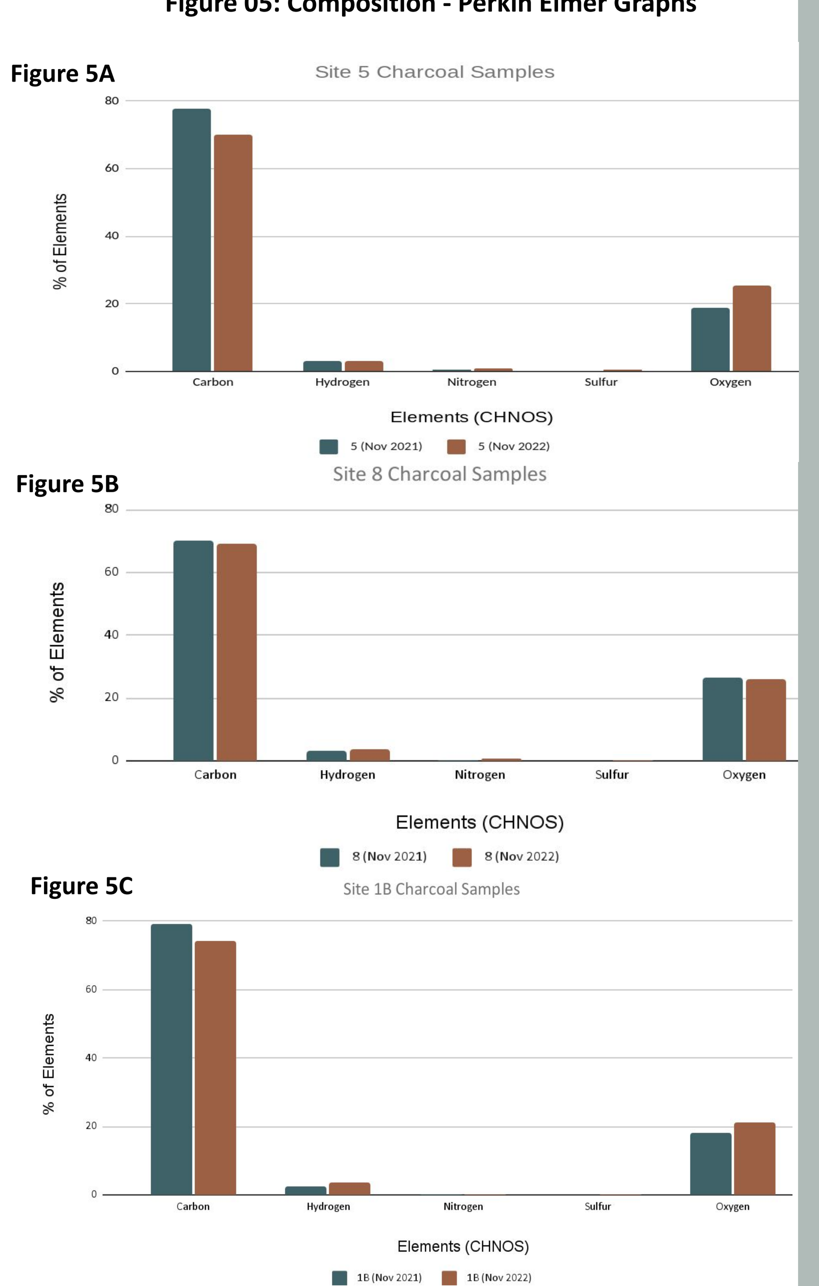

Figure 5A: displays the change in CHNSO composition of charcoal from site 5, indicating the loss of carbon and hydrogen atoms, while gaining oxygen, nitrogen and sulfur atoms after a year's time.

Figure 5B: indicates little to no overall change in elemental composition from site 8 despite minor changes. The graph displays no presence of sulfur, slight decreases in the amount of carbon and oxygen, and increase in hydrogen and nitrogen atoms.

Figure 5C: shows the change in CHNSO composition of charcoal from site 1B. No nitrogen or sulfur is ever present in the samples of charcoal. There is a decrease in carbon while an increase in oxygen and hydrogen atoms.

Discussions & Conclusions

- The 2022 charcoal from site 5 (Fig.4A) was a significantly better adsorption agent to Cd^{2+} than the previous charcoal in 2021.
- The 2022 charcoal from site 8 (Fig. 4B) was a significantly poorer adsorption agent indicated by their Cd^{2+} uptake from solution, the 2021 charcoal a better adsorption agent to begin with.
- The adsorption potential of charcoal from site 1B (Fig. 4C) stayed relatively constant, as neither sample was significantly weaker as an agent, the adsorption of both samples was high
- There is no obvious or direct correlation between the composition of charcoal (Fig. 5) and the change of reactivity to the metal. These results (behaviour and change of composition) may be due to external causes and processes such as weathering affecting these individual sites differently.
- Weathering by snowmelt and rainfall could impact the sites uniquely and to varying degrees depending on their locations, (by trees, the sides of a mountain, etc.) Weathering in one area might act to improve the adsorption ability but act to decrease the adsorption ability in another.
- Further work is necessary, as previous work indicates adsorption potential is dependent on the reactivity of the functional groups of a solid's surface [2]
- Potentiometric titrations and FTIR (Fourier Transform Infrared) Spectroscopic analysis would determine what functional groups are present on the charcoal's reactive surface and which specific functional groups are in use. Digestions would determine what other inorganic components are in the charcoal which may be posing as reactive sites as well, providing more context to its behaviour
- Implications of determining charcoal's role in mobilizing nutrients include understanding the origin, dynamics and fate of nutrients in freshwater and ocean environments
- Further applications and areas of research - if charcoal could be a remedy for increasing concentrations of these nutrients/contamination control [2]

Closing Remarks: The likelihood of charcoal changing metal and other nutrient transport patterns is variable, dependent on the extent of external processes and circumstances (weathering) effecting the reactive surfaces of charcoal and thus its ability to carry nutrients.

References

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4. (Lars J. Tranvik, August 2018, New light on black carbon, Vol 11, 546-549)

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