ADVANCES IN FOREST FIRE RESEARCH 2022

Edited by
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A Comparison of Particulate Morphology of Wildland Fuels and Human-Made Fuels at the Wildland-Urban Interface

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Keywords

Particulates; Wildland-Urban Interface (WUI) Fires; Scanning Electron Microscopy (SEM)

Abstract

A major outcome of large outdoor fires is the production of combustion products. The most well-known type of large outdoor fires are wildland fires that spread into developed, urban areas, known as wildland-urban interface (WUI) fires. Particulate emissions from WUI fires in California in 2018 resulted in almost a complete closure of San Francisco. Improved knowledge of large outdoor fire particulate emissions is needed at the laboratory-scale. Here, samples of oriented strand board (OSB), a common human-made fuel abundant in cities, were ignited using a radiant heater coupled to a spark igniter. Particulate samples were taken to begin to look at the morphology of the generated particulates. Using a simple experimental setup affords the capability to investigate particulates produced from smoldering combustion as well as those collected from flaming combustion. In this short paper, some initial results are presented fro OSB combustion. Further comparison to vegetative fuels will be presented at the conference.

1. Introduction

A consequence of large outdoor fires is the production of combustion products. These combustion products are known to cause extreme visibility issues and worries about health. Globally, the combustion of vegetative fuels is thought to be the prime supplier of particulate emissions and the second most supplier of gaseous emissions [Akagi *et al.*, 2011]. Particulate emissions from WUI fires in California in 2018 resulted in almost a complete closure of San Francisco.

Methodologies to determine emissions from wildland fires or biomass have centered on the concept of developing specific emissions factors (EF) [Akagi *et al.*, 2011]. EFs are usually reported for carbon monoxide, carbon dioxide, and particulate matter less than 2.5 microns. In many cases, EF do not account for the combustion of human-made fuels. It is obvious the vegetation species are not solely suppling the gaseous and particulate emissions but also the combustion processes from buildings, cars, buses, and other human-made combustibles only add to the assortment of emissions. Yet, it is not obvious how to addresses these additional complications.

Another overlooked, key shortcoming is that many of the EFs for vegetative fuels are predicated on controlled/prescribed fires. Specifically, these are well-controlled fires conducted for a variety of fire/fuel management intentions. Such controlled burning has benefits since it is performed over real terrain, but the fire exposure conditions cannot possibly recreate what is observed in the most dangerous fires. Typically, controlled fires are undertaken, under low ambient wind conditions to ensure safety yet massive, destructive fires rarely occur in low winds.

Complimenting EF research, there have been studies that have looked at the particulates formed in the context of wildland fires and as well as from biomass [Akagi *et al.*, 2011, Posfai *et al.*, 2003, Reid *et al.*, 2005]. None of this important research has been extended to WUI fires, where many non-vegetative fuels exist. What has been observed is that the nature of particles formed depend highly on the nature of the smoldering or flaming combustion properties of the wildland fires or biomass.

The reasons for this lie in the details of the combustion processes. In the case of smoldering combustion, and therefore smoldering fires, this is a surface process. Oxygen moves to the surface and reacts with fuels at relatively low temperatures. Since polycyclic aromatic hydrocarbons (PAH) are known to form at higher temperatures, smoke particles contain less soot for smoldering combustion as compared to flaming combustion. Particle formation are also known to occur around other nuclei other than PAHs [Lighty *et al.*, 2000]. For any type of large outdoor fire, there have been few studies of particulate formation in the smoldering phase and to the authors knowledge, almost no studies for engineered wood products found in WUI fires.

Results reported that for wildland fires or biomass that are in a state of smoldering combustion, the combustion processes are generally dominated by lower temperature regimes and therefore the collected particles have a liquid-like structure [Akagi *et al.*, 2011, Posfai *et al.*, 2003, Reid *et al.*, 2005]. For wildland fires or biomass that have higher temperatures, and are in a state of flaming combustion, these fires produce particles with more well-known fractal agglomerates and structure often seen in most soot formation studies in a state of flaming combustion (**see Figure 1).**

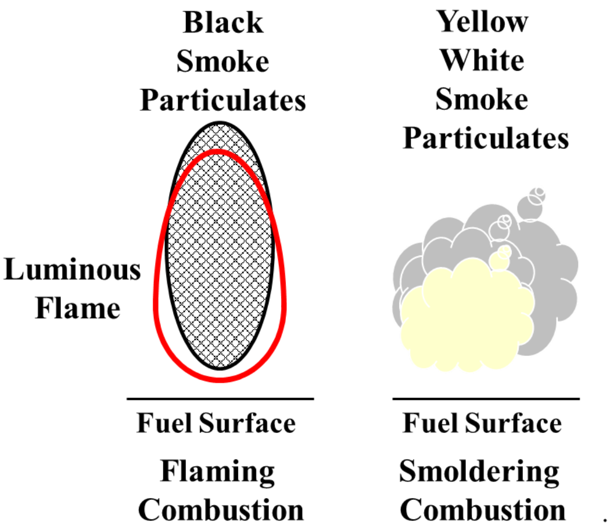

Figure 1- Differences in particulates observed during flaming combustion and smoldering combustion states.

Improved knowledge of large outdoor fire particulate emissions is needed at the laboratory-scale. Here, samples of oriented strand board (OSB), a common human-made fuel abundant in cities, were ignited using a radiant heater coupled to a spark igniter. Particulate samples were taken to begin to look at the morphology of the generated particulates. Using a simple experimental setup affords the capability to investigate particulates produced from smoldering combustion as well as those collected from flaming combustion.

As the nature of particulate samples were expected to be sensitive to the voltage of the electron beam for smoldering combustion in particular, scanning electron microscopy (SEM) was used as first step to investigate the morphology. Transmission electron microscopy (TEM) operates at higher acceleration voltages and this is expected to influence the samples. In this short paper, some initial results are presented fro OSB combustion. Further comparison to vegetative fuels will be presented at the conference.

2. Experimental Description

The experimental setup consisted of a radiant heater coupled to spark igniter (see **Figure 2**). Samples of OSB were cut into sizes of 100 mm by 100 mm. As commercial samples of OSB was used, the thickness was fixed at 11 mm.

The use of engineered wood products has been common worldwide. In the United States of America, there has been a move to replace plywood with OSB. In the past, plywood was more common. OSB is manufactured from smaller trees and is manufactured primarily of wood fragments, so it is cheaper to produce. Plywood requires thin, long sheets of wood veneers. Similar trends have been seen in other countries, including Japan.

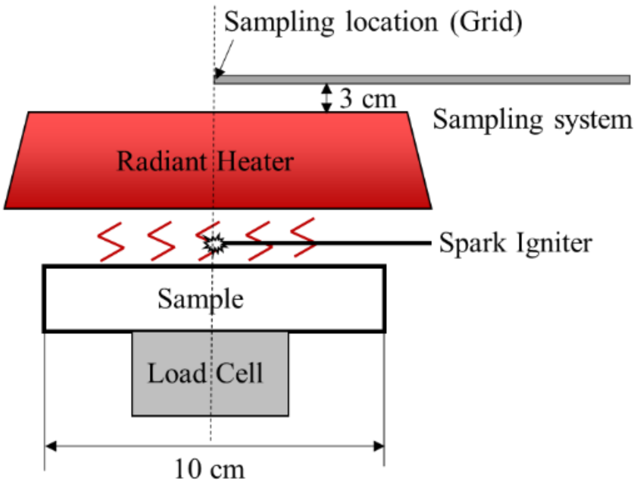

Figure 2- Schematic of Experimental Setup.

A radiant heat flux of 25-30 kW/m^2 was applied and the spark was operated continuously to produce flaming combustion. Under these conditions, the OSB samples ignited with sustained flaming ignition within 90 sec. Experiments were also conducted using a radiant heat flux of 25 kW/m^2, without the application of the spark, to produce smoldering combustion.

To sample particulates that are generated, the well-known principle of thermophoretic sampling was used. In the presence of a temperature gradient, the hot particles will be collected using cold grids that may be used for Scanning Electron Microscope (SEM) and Transmission Electron Microscopy (TEM) analysis. Presently, SEM was used a first step to image the overall structure of the particulate samples.

3. Results and Discussion

Experiments were conducted for one applied heat flux level and all samples were taken at the same time after the onset of sustained flaming combustion of the OSB sample. The total sampling time was varied from 1 sec to 3 sec. Figure 3 displays agglomerates imaged with the SEM for one of these sampling times.

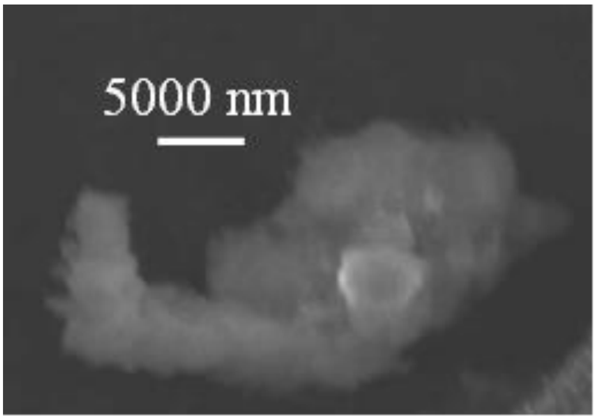

Figure 3 SEM image of particles collected from OSB in a state of flaming combustion (25 kW/m^2).

A series of experiments were conducted to sample the particulates generated from OSB samples in a state of smoldering combustion. The radiant heat flux was applied to the specimens and no spark was applied. Typical SEM images for the collected particulates from OSB undergoing smoldering combustion will be presented at the conference.

It is clear that the morphology of the particulates is indeed different depending on whether the OSB samples are in a state of flaming as opposed to smoldering combustion. Owing the higher temperatures during flaming combustion, the more well-known fractal agglomerate structures are observed for the OSB samples in a state of flaming combustion

4. Summary

Improved knowledge of large outdoor fire particulate emissions is needed at the laboratory-scale. Particulate samples were taken during both flaming combustion states and smoldering combustion states using thermophoretic sampling. As the nature of particulate samples were expected to be sensitive to the voltage of the electron beam for smoldering combustion in particular, scanning electron microscopy (SEM) was used as first step to investigate the morphology The nature of the combustion state resulted in vast differences in the morphology of the collected samples. Further comparison to vegetative fuels will be presented at the conference.

5. References

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