Differential Lung Toxicity of Biomass Smoke from Smoldering and Flaming Phases Following Acute Inhalation Exposure
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Abstract & Background
We previously demonstrated that, on a mass basis, lung toxicity associated with particulate matter (PM) from flaming smoke aspired into mouse lungs is greater than smoldering PM. This finding however has to be validated in inhalation studies to better predict real-world exposures. Thus, we modified an existing combustion system to precisely control and maintain smoke concentrations during the combustion process. We generated biomass smoke from peat and eucalyptus fuels under smoldering and flaming phases for up to 1 hour, and measured PM and volatile organic compounds (VOCs) levels. Smoldering PM levels were ~10 times higher than flaming PM with carbon monoxide (CO) at similar levels to equate potentially interfering CO health effects. Mice were exposed by inhalation for 1 hour/day for 2 days and then assessed for lung toxicity at 4 and 24 h after the second exposure. PM levels were ~40 and ~4 mg/mL under smoldering and flaming phases, respectively, while CO levels ranged from ~60 to 110 ppm for all exposures. Notably, VOCs PM ratios were higher (up to 7 times) in flaming than smoldering smoke. Smoldering peat and eucalyptus smoke elicited significant inflammation (neutrophils) in mouse lungs at 4 h post-exposure while flaming smoke from either fuel caused even greater lung inflammation at 24 h post-exposure. Similarly, a significant increase in an index of airway obstruction was observed in mice exposed to flaming peat and eucalyptus, and smoldering eucalyptus smoke immediately after each day of exposure. These results suggest that although smoking smoke contains much less PM mass than smoldering smoke, the health risk of this exposure is, on a mass basis, greater than that from smoldering emissions. These observations support the concept that health risks of smoke exposure vary depending on the type of fuel, combustion conditions, and particle chemistry.

Materials & Methods
Tested biomass fuels and their distribution in the United States

Biomass combustion and smoke collection system

Aspiration Exposure Study

Results

Aspiration Exposure Study

Flaming

Smoldering

More than 40% of particles were <100 nm

Smoldering PM levels were ~10 times higher than flaming PM with CO held at similar levels to equate potentially interfering CO health effects.

Figure 4: Biological responses to the biomass smoke exposure

Peat smoke produced under either combustion conditions caused similar increases in neutrophil (PMN) influx at both timepoints despite the flaming PM containing being 10-fold lower.

PMN responses to eucalyptus smoldering were higher than flaming although effects were equivalent for both conditions by 24 h.

No PMN effect was seen following exposure to either combustion condition of oak.

Conclusions

Type of fuel and combustion conditions have dramatic differences in emission characteristics, mutagenicity, and lung toxicity.

Forest composed largely of eucalyptus and pine produced emissions that could cause greater health effects than comparable fires from forests composed of the other types of biomass fuels.

Inhalation studies conducted with the automated combustion system can validate responses seen in aspiration exposure studies after adjustment for PM dosimetry.

The automated combustion system is capable of controlling combustion phases and PM concentrations and also can be employed for health risk assessment from inhalation exposure to wild fire smoke.

Future Work

Photochemically aged biomass smoke study

Diagram of an aged biomass smoke inhalation system

Figure 6: Lung toxicity: Aspiration vs. Inhalation

Aspiration PM dose

Inhalation PM dose

PM dosimetry analysis results show good concordance in responses between aspiration and inhalation studies depending on type of fuel and combustion conditions.


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