Assessing occupational woodsmoke exposure in firefighters

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Background

• Every year 100,000 people in the United States are exposed to woodsmoke via recreational burning, agricultural burning, wildfires and prescribed burns.
• Additionally, 80,000 firefighters are exposed to elevated levels of woodsmoke annually, many of which wear little to no respiratory equipment.
• Exposure to elevated levels of woodsmoke has been linked to asthma, reduced lung function, lung cancer and respiratory disease.
• Equipment designed to reduce woodsmoke.

In the past, carbon monoxide (CO) and particulate matter less than 2.5 μm in diameter (PM2.5) have been used to assess woodsmoke exposure, but both can be confounded by non-woodsmoke sources.

• The sugar anhydride levoglucosan (Fig. 1) is derived when cellulose undergoes pyrolysis making it a source-specific marker for cellulose combustion.
• A reliable, woodsmoke specific compound, such as levoglucosan (LG), could more accurately measure woodsmoke exposure levels.

Goal

• Collect filter samples from wildland firefighters near the Savannah River in Georgia while they perform prescribed burns.
• Measure CO, levoglucosan and PM2.5 levels.
• Determine if levoglucosan reliably correlates with CO and PM2.5 concentrations when woodsmoke is the sole source of PM to evaluate if levoglucosan may be used to more accurately assess woodsmoke exposure.

Methods

Exposure Assessment:

• 18 wildland firefighters sampled while performing prescribed burns near the Savannah River in Georgia January-March of 2009.
• Draeger PAC III single gas meters used for CO data-logging
• 1 min intervals, time-weighted average (ppb)
• Personal Breathing zone data
  * SKC Air Chek Pump (Ave flow 1.5 L/min, CV=0.6%)
  * PM2.5 collected on Gelman 37mm Teflon filters w/ PTFE membranes and 2.0 μm pore size connected to SKC pump
  * PM2.5 concentration (µg/m³) calculated using gravimetric analysis

LG Extraction and Derivatization:

* Filters spiked with deuterated-LG (D7-LG) prior to extraction to be able to measure analyte recovery
* Filters extracted via sonication in ethylacetate
* Sample volume reduced under N2, to concentrate extract
* Derivatized with MSTFA/pyridine to protect hydroxyl groups for GC/MS analysis

GC/MS Analysis:

* 1 µL of derivatized extract injected into GC
* Vaporized and swept through the GC column via an inert gas (Helium)
* Different compounds have different partition coefficients for the stationary phase lining the GC column, reaching the end of column at different times (retention times)
* Sample components then ionized by electron impact ionization
  * Mass to charge ratio (m/z) determined and used to identify sample components
  * LG has a unique ion of m/z 204 for quantification and 339 for confirmation

Results

* A total of 58 out of 72 filters collected from 18 firefighters in early 2009 had all necessary data
* LG Quality Control:
  - Average D7-LG recovery: 63% (CV: 15%)
  - Average LG blank concentration: 0.013 µg/m³ (SD: 0.017 µg/m³)

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<thead>
<tr>
<th></th>
<th>LG (µg/m³)</th>
<th>LG (µg/m³)</th>
<th>PM2.5 (µg/m³)</th>
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*No workers over OSHA Permissible Exposure Limit (PEL) for PM2.5 (PEL PM2.5=5000 µg/m³, PEL for PM2.5 not available)
*EPA annual average NAAQS (National Ambient Air Quality Standards) for PM2.5 should not exceed 35 µg/m³

Analysis of 2008 & 2009 Combined Savannah River Data

*LG concentrations are correlated with PM2.5 concentrations

Conclusion

* Both 2008 and 2009 data show that wildland firefighters are exposed to elevated levels of LG and PM2.5.
* LG and PM2.5 are significantly correlated suggesting that LG is a suitable biomarker for assessing woodsmoke exposure.

Next Steps

* Compare LG and PM2.5 concentrations with CO concentrations
* Separate data according to forest region burned to assess differences between hardwood and softwood combustion
* Compare LG levels to woodsmoke metabolites in urine (methoxyphenols) to assess their validity as human woodsmoke exposure biomarkers

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