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[1]

•Additionally, 80,000 firefighters are exposed to elevated levels of woodsmoke annually, many of which wear little to no respiratory equipment[1]

•Exposure to elevated levels of woodsmoke has been linked to asthma, reduced lung function, lung cancer and respiratory disease[2]

•Accurately assessing levels of exposure has been difficult due to the complex mixture of gases and particles that make up woodsmoke

•In the past, carbon monoxide (CO) and particulate matter less than 2.5 µm in diameter ($PM_{2.5}$) have been used to assess woodsmoke exposure[3], but both can be confounded by non-woodsmoke sources[4]


http://picture-book.com

• The sugar anhydride levoglucosan (Fig. 1) is derived when cellulose undergoes pyrolysis making it a source-specific marker for cellulose combustion[4]

• A reliable, woodsmoke specific compound, such as levoglucosan **(LG),** could more accurately measure woodsmoke exposure levels

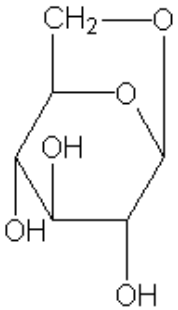
Goal

•Collect filter samples from wildland firefighters near the Savannah River in Georgia while they perform prescribed burns

•Measure CO, levoglucosan and $PM_{2.5}$ levels

•Determine if levoglucosan reliably correlates with CO and $PM_{2.5}$ concentrations when woodsmoke is the sole source of PM to evaluate if levoglucosan may be used to more accurately assess woodsmoke exposure

Figure 1: Structure of Levoglucosan



1,6-anyhdro-B-D-glucopyranose

Methods


http://enviro-x.com/catalog

Figure 2: SKC Air Chek Pump

Exposure Assessment:

• 18 wildland firefighters sampled while performing prescribed burns near the Savannah River in Georgia January-March of 2009

•Draegar 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 1.50 L/min,CV=.068%) connected to a BGI Inc GK2.05 (KTL) $PM_{2.5}$ cyclone
* $PM_{2.5}$ collected on Gelman 37mm Teflon filters w/ PTFE membranes and 2.0 µm pore size connected to SKC pump
* $PM_{2.5}$ concentration (µg/ m^3) calculated using gravimetric analysis

LG Extraction and Derivatization:

* Filters spiked with deuterated-LG (**D_7-LG**) prior to extraction to be able to measure analyte recovery
* Filters extracted via sonication in ethylacetate
* Sample volume reduced under N_2 to concentrate extract
* Derivatized with MSTFA/pyridine to protect hydroxyl groups for GC/MS analysis

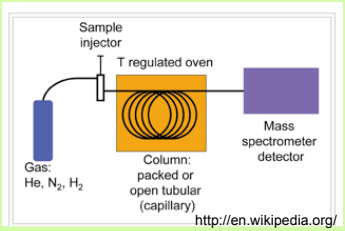


Figure 3: GC/MS schematic

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

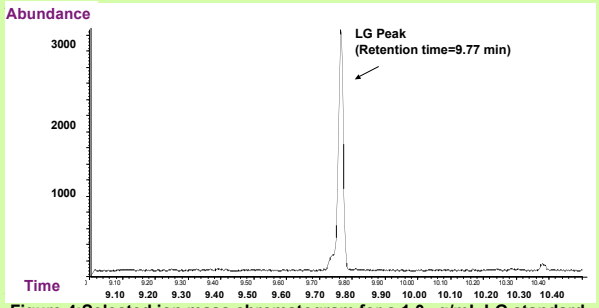


Figure 4:Selected ion mass chromatogram for a 1.0 µg/mL LG standard

Results

* A total of 58 out of 72 filters collected from 18 firefighters in early 2009 had all necessary data
* LG Quality Control:
  - Average D_7-LG recovery: 63% (CV: 15%)
  - Average LG blank concentration: 0.013 µg/m^3 (SD: 0.017 µg/m^3)

Table 1 Comparison of descriptive statistics for 2008 and 2009

	LG (µg/m^3) 2009	LG(µg/m^3) 2008	$PM_{2.5}$ (µg/m^3) 2009	$PM_{2.5}$ (µg/m^3) 2008
N	58	71	58	71
Mean	66	24	732	553
Median	21	19	587	514
Max	291	97	2070	1470
Min	0.041	1.4	143	50

*No workers over OSHA Permissible Exposure Limit (PEL) for PM_4 (PEL PM_4 =5000 µg/m^3, PEL for $PM_{2.5}$ not available)
*EPA annual average NAAQS (National Ambient Air Quality Standards) for $PM_{2.5}$ should not exceed 35 µg/m^3

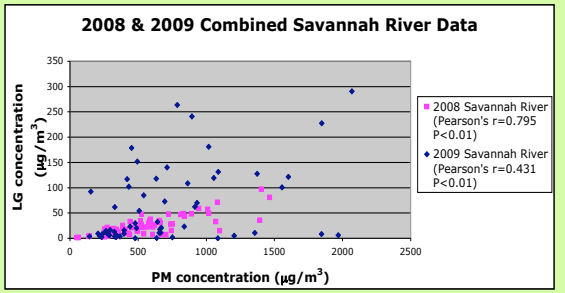


Figure 5: Combined 2008 and 2009 Savannah River sampling data

*LG concentrations are correlated with $PM_{2.5}$ concentrations

Conclusion

*Both 2008 and 2009 data show that wildland firefighters are exposed to elevated levels of LG and $PM_{2.5}$.
* LG and $PM_{2.5}$ are significantly correlated suggesting that LG is a suitable biomarker for assessing woodsmoke exposure

Next Steps

* Compare LG and $PM_{2.5}$ 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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References: **[1] Harrison R., Materna B.L., and Rothman, N. (1995) *Occup Med:* 10:857-870 [2] Naeher L.P., Achtemeier G.L., Glitzenstein L.S., Streng D.R., and Macintosh D. (2006) *J Expo Sci Environ Epid* 16:351-361 [3] Reinhardt T.E. and Ottomar P.D.(2004) *J Occup Environ Hyg* 1:593-606. [4] Neitzel R., Naeher L.P., Paulsen M., Dunn K., Stock A., and Simpson C.D. (2008) *J Expos Sci Environ Epid* 1:1-10**