Skin Exposure and Absorption of Polycyclic Aromatic Hydrocarbons (PAHs) in Firefighters

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• Urinary biomarker studies show that both urban (structural) and wildland firefighters are exposed to polycyclic aromatic hydrocarbons (PAHs).

• The importance of routes of exposure may differ – wildland firefighters do not wear respiratory protection (RPE).

• Skin exposure, during the fire and from clothing/equipment reused without adequate cleaning, is likely to be important for both urban and wildland.
ACGIH recommends urinary 1-hydroxypyrene as a biomarker of PAH exposure with samples taken at the end of the shift at the end of the work week.

Although half life is assumed to be of the order of 18 hours, a two (or three) compartment model has also been reported with the slowest component having a half-life of 16 days (Jongeneelen, 1988)
• Fort McMurray: some 80,000 inhabitants, hub of the Northern Alberta oil and gas industry.
• Total evacuation 3rd May 2016.
• 3200 firefighters from throughout Alberta.
• Firefighting within the conurbation most intense in early–mid May: continued burning away from the urban area
Exposure estimates for individual firefighters by start of deployment
Exposure concentration PAHs
Structural firefighters deployed to fight the fire (and wildland outside the city).

In the chaos of the first few days, no (effective) use of RPE

Very few facilities for washing, showering, change of clothes.

Great possibilities for skin exposures.
Fire fighters were interviewed, urine samples collected and a Skin Exposure Mitigation Index (SEMI) constructed from answers to three questions

• In breaks within shift, were there facilities for you to wash?
• Between shifts, were you able to shower?
• Between shifts were you able to change into clean clothes?
Low scores on the SEMI were found only during the first week of the fire. After that firefighters, showered and changed into clean clothes between shifts.

So the analysis related only to those exposed in the first week.

But first urine samples taken two weeks after the fire started.
Exposure estimates for individual firefighters by start of key deployment

W: urban threat begins  X: high exposures end  Y: first urines collected service "A"  Z: first urines collected service "B"
We found a relation between poor skin hygiene and urinary 1-hydroxypyrene (1-HP) in urine samples 10 days after exposure.

<table>
<thead>
<tr>
<th>Skin hygiene index</th>
<th>Mean 1-Hpug/g creat</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hygiene</td>
<td>221</td>
</tr>
<tr>
<td>Poor</td>
<td>74</td>
</tr>
<tr>
<td>Better</td>
<td>67</td>
</tr>
<tr>
<td>Best</td>
<td>50</td>
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*test for trend p=0.003*  

*Cherry et al ANNWEH, 2019*
Study 2:
Evaluation of PAH exposures and 1-HP in \textit{wildland} firefighters.

- Urine samples before shift, after shift and next morning.
- Skin wipes before/after shift
- Sample of clean shaven volunteers assigned to masks (N95:P100)
- Random allocation (50:50) to enhanced hygiene/normal practice
- Pumps to confirm presence of PAH
- Next morning questionnaires to confirm hygiene, symptoms, mask
To date have evaluated 86 firefighters from 11 fire/days in Alberta and British Columbia.

Results today from pumps at first 7 fires.
Urines for 1-HP from 31 firefighters
Skin wipes for PAH from 21 firefighters in BC
Next morning questionnaires from 85 firefighters.
Pumps confirm the presence of PAHs. Assessed for 11 PAHs by the IRSST (Montreal) in particulates and in vapour phase.

12/18 pumps were positive for one or more PAH.
(11/12 Alberta: 1/6 BC)

**Particulates:**
- benzo(b,j,k)flouranthene (5/18)
- pyrene & benzo(a)pyrene (1/18)

**Vapour phase:**
- phenanthrene (7/14)
<table>
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<tr>
<th></th>
<th>Alberta</th>
<th>BC</th>
<th>both</th>
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<tbody>
<tr>
<td>Pre-shift</td>
<td>143</td>
<td>148</td>
<td>146</td>
</tr>
<tr>
<td>Post-shift</td>
<td>256</td>
<td>174</td>
<td>200</td>
</tr>
<tr>
<td>Next morning</td>
<td>213</td>
<td>120</td>
<td>150</td>
</tr>
<tr>
<td>p=</td>
<td>0.87</td>
<td>0.04</td>
<td>&lt;0.01</td>
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Urine (nano-g/g) 1-HP post-next morning: loss with hygiene

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<th>BC</th>
<th>both</th>
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</thead>
<tbody>
<tr>
<td>Enhances hygiene</td>
<td>36</td>
<td>73</td>
<td>60</td>
</tr>
<tr>
<td>Normal practice</td>
<td>54</td>
<td>27</td>
<td>36</td>
</tr>
<tr>
<td>Gain/Loss</td>
<td>+18</td>
<td>-46</td>
<td>-24</td>
</tr>
<tr>
<td>p=</td>
<td>0.79</td>
<td>0.13</td>
<td>0.37</td>
</tr>
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Skin wipes
As method still being validated, only 21 skin wipes collected **extra to protocol** analysed to date.

Area on shin above boots as the request of BC firefighters.
Hot-spotting in coniferous forest

No PAH found – but none in air samples and little in urine.
Next morning questionnaires: completed by 85/86.

<table>
<thead>
<tr>
<th>Enhanced hygiene</th>
<th>Normal practice</th>
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<tbody>
<tr>
<td>Mean hours end shift to shower</td>
<td>2.1</td>
</tr>
<tr>
<td>% changing 5+ garments</td>
<td>41%</td>
</tr>
<tr>
<td>N</td>
<td>44</td>
</tr>
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Conclusions from Study 2?

Design feasible and (some) exposure but

- Need results from more samples (86+ rather than 31)
- Exclude or adjust for extraneous exposures (2nd hand smoke etc)
- More meaningful ‘enhanced hygiene’: camp rather than day trippers
Study 3: Proposed quasi-experimental design for intervention.

8 forestry management areas to be randomised to one of:

- RPE only
- Skin hygiene only
- RPE and skin hygiene
- Normal practice

Each management area to follow same regime throughout the 2020 fire season.
Key features of plan as proposed

• RPE to be determined from current field studies
• Enhanced skin hygiene: provision of laundry and showers with the expectation of clean clothing after every working day.
• Urine samples to be collected at the beginning and end of each 14 day deployment
• PAH (1-HP) analysed in pooled samples to avoid prohibitive costs.
Study 3 Quasi-experimental intervention

Lessons from current study.

• RPE badly tolerated (?)
• Research manpower demands/costs high for each field trip
• Unrealistic to expect crews to collect and store own urine
• Need to reduce scope of project to fit resources (research team and budget).
Ideas for feasible intervention?

• Concentrate intervention on improved skin hygiene
• 4 crews (2 enhanced, 2 normal practice) throughout the season.
• Collect urines at start/end of first deployment and at end of each subsequent deployment.
• As a separate investigation, test acceptability/efficacy of alternate RPE
Would welcome ideas/suggestions on design of (funded!) intervention study