Biological monitoring of asphalt workers by urinary 1-hydroxypyrene: comparison between outdoor and indoor paving

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Summary

Introduction: this study investigates urinary excretion of 1-hydroxypyrene (1-OHP) in 108 asphalt workers, who carried out daily activities adhering scrupulously to the preventive and protective policies laid down by “Regione Lombardia”.

Objectives: we want to evaluate the sensitivity of the assay of urinary hydroxypyrene as a descriptor of exposure to polycyclic aromatic hydrocarbons and evaluate the contribution of smoking on urinary 1-OHP.

Methods: values found after two days of asphalt working and values after two days of inactivity were compared. Readings were also compared between smokers and non-smokers, and between outdoor and indoor paving.

The statistical evaluation of the data was performed using the Student t test.

Results: differences of urinary 1-OHP values measured in the same workers after 2 days of inactivity, and values after 2 days spent in asphalt working were not statistically significant. Differences between readings emerged in case of outdoor paving. No significant differences between smokers and non-smokers were found.

Conclusions: urinary 1-OHP is a biomarker that better correlates with exposure to fumes of bitumen, but only when exposure is high, as it is the case during indoor asphalt working; in cases of low exposure, increase in the urinary excretion of the marker cannot be statistically significant. Cigarette smoking, known for interfering with this indicator of exposure, could have limited its specificity, but did not significantly contribute in tests done in absence of occupational exposure.

KEY WORDS: asphalting, bitumen, PAH, oncogenic risk, prevention.

Introduction

Paving using bituminous mixtures involves a work-related exposure which depends on amount of time spent working and on the specific activity done. Variability of exposure is more relevant in terms of quantity than (for) quality of chemical hazards. Substances involved, mostly represented by polycyclic aromatic hydrocarbons (PAH), can be a hazard through different penetration ways (1-4). Bitumen which is used as glue mixed with aggregate particles to create asphalt concrete, is a non volatile residue of petroleum refining process. Due to low levels of aromatic substances contained, bitumen is not classified by EU as carcinogen, as opposed to tar, a substance with similar uses but produced by coal refinery. Bitumen’s usefulness in paving is because it is solid at room temperature and fluid or liquid at higher temperatures, therefore it is used between 150/180° C. The operating temperatures are much lower than boiling temperatures of single PAH. Melting and boiling temperatures of the most represented PAH of bitumen are listed below.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Melting (°C)</th>
<th>Boiling (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acenaphthene</td>
<td>95</td>
<td>279</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>91,8</td>
<td>275</td>
</tr>
<tr>
<td>Anthracene</td>
<td>217</td>
<td>340</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>162</td>
<td>436,7</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>177</td>
<td>495</td>
</tr>
<tr>
<td>Benzo(b)fluoranthe</td>
<td>168</td>
<td>481</td>
</tr>
<tr>
<td>Benzo(g,h,i)peryene</td>
<td>278</td>
<td>500</td>
</tr>
<tr>
<td>Benzo(k)fluoranthe</td>
<td>215</td>
<td>480</td>
</tr>
<tr>
<td>Chrysene</td>
<td>254</td>
<td>448</td>
</tr>
<tr>
<td>Dibenzo(a,h)anthracene</td>
<td>266</td>
<td>524</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>96</td>
<td>340</td>
</tr>
<tr>
<td>Fluoranthe</td>
<td>109</td>
<td>384</td>
</tr>
<tr>
<td>Fluorene</td>
<td>116</td>
<td>295</td>
</tr>
<tr>
<td>Indeno(1,2,3-c,d)pyrene</td>
<td>164</td>
<td>497</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>79</td>
<td>218</td>
</tr>
<tr>
<td>Pyrene</td>
<td>145</td>
<td>404</td>
</tr>
</tbody>
</table>

As shown in the chart, naphthalene, a non carcinogenic PAH, has the lowest boiling temperature which is at least 40° C higher than that bitumen is utilized. So during usual paving working a massive phase change from
liquid (or in some cases solid) to gas state is not possible. Obviously a little part of these aromatics changes to gas but expected values are so low to be indistinguishable from other molecules coming from other sources like traffic and home heating. Such phenomena are described in the “Vademecum for improving Workers’ Health and Safety in Asphalt Works” released by Regione Lombardia in June 2006 and updated in 2011, which suggests who is going to measure aerosol dispersed dPAHs through an analytic method sensible enough to allow measurements within the order of ng. The increase of bitumen temperature, due to its processing, results in an increase of airborne PAHs. The relevance of their presence in air and the correlate deposition of workers is the basis of the possible risk for workers’ health (5-7). In usual conditions, exposition does not appear to be relevant, but there are some particular situations in which PAHs gases can amass and their concentration in air becomes higher, as it is the case in indoor paving. Respiratory hazard is not the only one because during working activities a skin contact with bitumen may occur in the presence of dirty tools and also from contaminated clothes or personal protective equipment (8, 9). Environmental surveys cannot determine all these kinds of exposition, so a biomarker that better correlates with exposure to fumes of bitumen is needed (10). Urinary 1-hydroxypyrene is a metabolite of pyrene, a non-carcinogenic PAH, whose presence is constantly correlated to total PAH (11-13). For this reason, the ACGIH believes that the urinary 1-OHP measured at the end of work shift at the end of the workweek, is a biological indicator of exposure to polycyclic aromatic hydrocarbons (14). The ACGIH classifies this biomarker as NQ, non quantitative, probably due to lack of correlation between exposure and excretion of metabolite (15).

Objectives

To evaluate the sensitivity of the assay of urinary hydroxypyrene as a descriptor of exposure to polycyclic aromatic hydrocarbons in standard conditions and in higher hazard environment as in case of indoor paving. Moreover, several factors interfering with liability of 1-OHP as biomarker are reported in literature; one of the most important is smoke, so its contribution of urinary excretion of 1-OHP has been evaluated and sized.

Methods

A sample of 108 asphalt workers with different specific tasks, all exposed to bitumen fumes and also to skin contact with bitumen. The tasks were: ground operator, road paver driver, roller compactor operator and service guy. Both outdoor and indoor paving were considered. Workers did their daily activities adhering scrupulously to the preventive and protective policies laid down by “Regione Lombardia” in the “Vademecum for improving Workers’ Health and Safety in Asphalt Works”. Listed below are main features of this document.

 Norms of personal hygiene and work

- Avoid contact with dirty equipment and with the bitumen emulsion, lubricating oil, diesel oil and fats, especially during cleaning and maintenance of vehicles.
- Keep the skin clean and dry.
- Wash frequently hands and face.
- Clean hands after using the toilet.
- Take a shower after extraordinary maintenance work.
- Keep clothes clean.
- Do not eat, drink or smoke during production of asphalt and paving.

Protective clothing

- Full work suits, or long pants and long sleeve shirt, which have to ensure proper protection from weather.

PPE and its use policy

- Heat-resistant gloves.
- Footwear with heat-resistant soles.
- Disposable tyvek suit in case of manual spraying of bituminous emulsion.
- Safety glasses with side protection in case of manual spraying of emulsion.
- Class 2 facial dust filter with activated carbon (FFP2SL) for indoor paving of roads (tunnels, etc.) or sidewalks (underpasses, etc.).
- Organize a program of cleaning, maintenance and verification of the efficiency of PPE with appropriate periodic inspections and after each use, ensuring new staff as soon as necessary.
- Provide each worker with individual containers where placing supplied PPE.

Workers were grouped according to the activity carried out two days before their urinary 1-OHP was measured and to the number of cigarettes smoked. A urine sample was collected from every worker on Monday, after two days of inactivity and another one at the end of work shift after two days of a full indoor or outdoor activity. Comparisons were performed between the different 1-OHP values following this scheme.

<table>
<thead>
<tr>
<th>REF</th>
<th>GROUP</th>
<th>CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sample after 2 days of inactivity</td>
<td>Sample after 2 days of activity</td>
</tr>
<tr>
<td></td>
<td>108 cases</td>
<td>108 cases</td>
</tr>
<tr>
<td>2</td>
<td>Sample after 2 days of inactivity</td>
<td>Sample after 2 days of activity</td>
</tr>
<tr>
<td></td>
<td>Non smokers</td>
<td>smokers</td>
</tr>
<tr>
<td></td>
<td>41 cases</td>
<td>67 cases</td>
</tr>
<tr>
<td>3</td>
<td>Sample after 2 days of outdoor activity</td>
<td>Sample after 2 days of outdoor activity</td>
</tr>
</tbody>
</table>
Values of urinary 1-OHP are expressed in µg/gram creatinine. Unpaired or paired t-tests were used to compare values.

**Results**

1. Dosage of urinary 1-OHP after 2 days of inactivity vs the same examination, the same people, after 2 days of activities on site or tunnel: 108 observations, first sample average 0.35, second sample average 0.65, mean difference 0.30, t values (1.92) close to the margin of statistical significance (p<0.05 if t >1.96).

2. Dosage of urinary 1-OHP after 2 days of inactivity, non smokers vs smokers; 1st sample: Observations 41 mean 0.29; 2nd sample: Observations 67 mean 0.39, Mean difference 0.1 t values not significant.

3. Dosage of urinary 1-OHP after 2 days of outdoor activity vs the same examination, after 2 days of indoor activities. 1st sample: Observations 18 mean 1.75; 2nd sample: Observations 90 mean 0.46, Mean difference 1.29; t values are significant, p<0.05.

4. Dosage of urinary 1-OHP after 2 days of inactivity vs the same examination, the same people, after 2 days of indoor activities. 18 observations, first sample average 0.34, second sample average 1.75, mean difference 1.41, significant t values (p<0.05).

**Conclusions**

This study found differences in urinary 1-OHP between measurement after activities and samples taken after two days of inactivity (0.65 vs 0.35). This difference was not significant but value is very close to the limit of significance; a scrupulous adoption of prevention criteria may have determined this loss of significance. The comparison between smokers and non smokers led to not significative differences (0.29 vs 0.39). Differences become significative in comparing samples from outdoor and from indoor workers (1.75 vs 0.46). Also comparison between samples from the same people after two days of inactivity and after two days of indoor asphalting was significant (0.34 vs 1.75), p<0.05. Results suggest that when workers adhered scrupulously to the preventive and protective policies, the measure of urinary 1-OHP was correlated with bitumen fumes exposure in indoor paving, while it was not statistically significant in outdoor activities. Smoking does not seem to interfere with specificity of the biomarker. Further perspective of study can be the research of a correlation between environmental values of PAH in indoor paving and urinary 1-OHP.

**References**


