BIOLOGICAL MONITORING OF ASPHALT WORKERS BY URINARY 1-HYDROXYPYRENE: COMPARISON BETWEEN OUTDOOR AND INDOOR PAVING

MONITORAGGIO BIOLOGICO MEDIANTE 1-IDROSSIPIRENE URINARIO IN ASFALTATORI: CONFRONTO TRA LAVORAZIONI IN ESTERNO E IN AMBIENTE CONFINATO

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Key words: asphalting, bitumen, PAH, oncogenic risk, prevention

Parole chiave: asfaltatura, bitume, IPA, rischio oncogeno, prevenzione
Abstract

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.

Results: Differences of urinary 1-OHP values measured in the same workers after 2 days of inactivity, and values after two days spent in asphalting were not statistically significant, while a significant association between the two readings emerged in case of indoor asphalting. 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 asphalting; 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.


Abstract

Introduzione: Lo studio valuta l’escrezione urinaria di 1-idrossipirene (1-OHP) in 108 lavoratori dell’asfalto che svolgevano la loro attività attenendosi scrupolosamente a criteri di carattere preventivo e protettivo coerenti con le specifiche indicazioni della Regione Lombardia.

Obiettivi: Valutare la sensibilità del dosaggio dell’idrossipirene urinario come descrittore dell’esposizione a idrocarburi policiclici aromatici e valutare il contributo del fumo sull’escrezione urinaria dell’1-OHP.

Metodi: Sono stati confrontati valori rilevati dopo 2 giorni di asfaltatura con valori dopo 2 giorni di inattività. Sono stati inoltre eseguiti confronti tra fumatori e non fumatori, e tra realizzazioni di pavimentazioni stradali all’aperto e asfaltatura in luoghi confinati.

Risultati: Sono state riscontrate differenze non statisticamente significative nel dosaggio dell’1-OHP dopo asfaltatura rispetto all’1-OHP dopo inattività, eseguito nei medesimi soggetti. Tali differenze assumono invece significatività nel gruppo che ha svolto attività in ambiente confinato. Anche il confronto tra fumatori e non fumatori ha rilevato differenze non statisticamente significative.

Conclusioni: L’1-OHP urinario è un indicatore che correla meglio con l’esposizione a fumi di bitume quando questa è particolarmente elevata, come avviene durante le operazioni di asfaltatura in luoghi confinati, mentre in caso di esposizioni molto basse, gli incrementi nella escrezione urinaria dell’indicatore, pur presenti, possono non assumere significatività statistica. Il fumo di sigaretta, noto per la sua interferenza con l’indicatore di esposizione esaminato, potrebbe averne limitato la specificità, ma non ha prodotto alterazioni significative nei test eseguiti in assenza di esposizione.
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 quality of chemical hazards.

Substances involved, mostly represented by polycyclic aromatic hydrocarbons (PAH), can be a hazard through different penetration ways (1, 2, 3, 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 is useful in paving because it is solid at room temperature but fluid or liquid at higher temperatures, therefore it is used between 150°/180° C.

Operating temperatures are much lower than boiling temperatures of each PAH.

Melting and boiling temperatures of the most common PAH present in the 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)fluoranthene</td>
<td>168</td>
<td>481</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
<td>278</td>
<td>500</td>
</tr>
<tr>
<td>Benzo(k)fluoranthene</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>Fluoranthene</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 table, naphthalene, a non carcinogenic PAH, has the lowest boiling temperature which is at least 40° C higher than that bitumen is utilized. This is why 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 to measure aerosol dispersive dPAHs through an analytic method sensible enough to allow measurements within the order of ng. The increase of bitumen temperature, during its processing, results in an increase of airborne PAHs.

The relevance of their presence in air and the correlate deposition of workers are the basis of the possible risk for workers health (5, 6, 7).

In base conditions, exposition does not appear to be relevant but there are some particular situations when the PAHs 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 individual 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, 12, 13).

For this reason, the ACGIH believes that the urinary 1-OHP measured at the end of weekly 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 the lack of correlation between exposure and excretion of metabolite (15).

Objectives

To evaluate the sensitivity of the urinary hydroxypyrene assay 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 reliability 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”. The main features of this document are listed below.

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 cloche clean.
- Do not wear dirty or contaminated work clothes: do a periodical washing.
- Periodically replace suits and work clothes.
- Avoid contact between your clothes and work suit.
- Do not eat, drink or smoke during production of asphalt and paving

**Protective clothing**

- Full work suits, or long pants and long sleeve shirt, have to ensure appropriate protection from atmospheric agent.

**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, then after two days of inactivity and at the end of work shift then again after two days of 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 inactivity</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>
<tr>
<td></td>
<td>90 cases</td>
<td>18 cases</td>
</tr>
<tr>
<td>4</td>
<td>Sample after 2 days of inactivity</td>
<td>Sample after 2 days of indoor activity</td>
</tr>
<tr>
<td></td>
<td>18 cases</td>
<td>18 cases</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 versus the same test, the same people, after 2 days of activity 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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Observations</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>41</td>
<td>0.29</td>
</tr>
<tr>
<td>2nd</td>
<td>67</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Mean difference 0.1

T values not significant

3. Dosage of urinary 1-OHP after 2 days of outdoor activity versus the same test, after 2 days of indoor activity.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Observations</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>18</td>
<td>1.75</td>
</tr>
<tr>
<td>2nd</td>
<td>90</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Mean difference 1.29

T values are significant, p< 0.05

4. Dosage of urinary 1-OHP after 2 days of inactivity versus the same test, the same people, after 2 days of indoor activity. 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 the values after activities and the values after two days of inactivity (0.65 vs. 0.35). This difference was not significative but it was 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 became significative in comparing samples of outdoor and indoor workers (1.75 vs. 0.46).

Also the 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.

The results suggest that when workers adhered scrupulously to the preventive and protective policies, the measure of urinary 1-OHP was correlated to the bitumen fumes exposure in indoor paving, while it was not statistically significant in outdoor activities.

Smoking does not seem to interfere with the 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


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