

# CHEMICAL AGENTS AND RELATED OCCUPATIONS

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A REVIEW OF HUMAN CARCINOGENS

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opinions of an IARC Working Group on the  
Evaluation of Carcinogenic Risks to Humans,  
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TO HUMANS

# COAL-TAR PITCH

Coal-tar pitch and associated exposures were considered by previous IARC Working Groups in 1984, 1987, and 2005 ([IARC, 1985, 1987, 2010](#)). Since that time new data have become available, which have been incorporated in this *Monograph*, and taken into consideration in the present evaluation.

## 1. Exposure Data

### 1.1 Identification of the agent

Studies of coke-oven pitch indicate that coal-tar pitch contains: four-membered aromatic hydrocarbon ring systems (e.g. chrysene, fluoranthene, pyrene, triphenylene, naphthacene and benzanthracene); five-membered ring systems (picene, benzo[*a*]pyrene (B[*a*]P) and benzo[*e*]pyrene, benzofluoranthenes and perylene); six-membered ring systems (dibenzopyrenes, dibenzofluoranthenes and benzoperyles); and seven-ring systems (coronene). Other aromatic chemicals in coal-tar pitch include methylated and polymethylated derivatives, mono- and polyhydroxylated derivatives, and heterocyclic compounds ([Betts, 1997](#)).

For a more detailed description of the coal-tar distillation process, including coal-tar pitch, the reader is referred to *IARC Monograph Volume 92* ([IARC, 2010](#)), and to the *Monograph on Occupational Exposures during Coal-tar Distillation* in this volume.

### 1.2 Human exposure

#### 1.2.1 Occupational exposure

Coal-tar pitch is used in electrode manufacture, roofing and paving.

Studies examining exposures during roofing and paving published since the previous *IARC Monograph* ([IARC, 2010](#)) are summarized below.

##### (a) Roofing

The exposures associated with roofing are the result of two operations. First, the old roof is removed by cutting, prying and scraping the existing material from the roof, and discarding it. A new roof is then installed by melting solid blocks of coal-tar pitch, pumping or carrying buckets of the molten material to the roof, where layers of roofing felt and liquid coal-tar pitch are spread upon the surface to produce a cover ([NIOSH, 2000; IPCS, 2004](#)). Roofers are primarily exposed to PAHs. Other exposures include silica, diesel exhaust, asbestos and organic solvents. Recent studies on airborne concentrations of PAHs measured in roofing are summarized in [Table 1.1](#).

Studies in the USA showed that long after cessation of applying coal-tar pitch on roofs,

**Table 1.1 Concentrations of PAHs in the ambient air of workers in roofing with coal-tar pitch**

Reference Country Year of study	Job/task	No. of subjects	No. of samples	No. of smokers	PAH	Dermal Exposure (ng/cm <sup>2</sup> )		Urinary 1-OH- pyrene (µmol/ mol creatinine)
						Mean	Range	
<a href="#">McClean et al. (2007)</a> USA 1998	Tear-off of coal-tar roofs Roof workers	26	71	NR	Polycyclic aromatic compound	898	48–30014	
					Pyrene	11.0	< 2.4–221	
					B[a]P	3.3	< 0.5–59	
	Tear-off	NR	41	NR	Polycyclic aromatic compound	886	49–33538	
					Pyrene	11.5	< 2.4–168	
					B[a]P	4.6	< 0.5–84	
	Put-down	NR	56	NR	PAC	344	48–21437	
					Pyrene	3.8	< 2.4–150	
					B[a]P	1.0	< 0.5–59	
	Kettlemen	5	19	NR	Polycyclic aromatic compound	299	40–4558	
Pyrene					4.5	< 2.4–34		
B[a]P					0.9	< 0.5–20		
<a href="#">Toraason et al. (2001)</a> USA 1998	Tear-off of coal-tar roofs coal-tar tear-off exposure	16			start wk		Mean (SD)	
					end wk		0.74 (0.86)	
	asphalt-fume only exposure	6			start wk		0.26 (0.13)	
					end wk		0.58 (0.29)	
	controls	3			start wk		0.08 (0.12)	
					end wk		0.12 (0.12)	

B[a]P, benzo[a]pyrene; NR, not reported; SD, standard deviation; wk, week or weeks

workers can still be exposed to coal tar during tear-off of existing roofs ([Toraason et al., 2001](#); [McClellan et al., 2007](#)). Working with coal-tar pitch was associated with a sixfold increase in PAH exposure, an eightfold increase in pyrene exposure and a 35-fold increase in benzo[*a*]pyrene exposure. Urinary 1-OH-pyrene concentrations in workers and controls showed a fivefold difference at post-shift and a 7.2-fold difference several hours later, which shows the importance of dermal exposure resulting in a prolonged uptake after the end-of-shift.

### (b) Paving

Roadway paving can be conducted by several methods, including hot-mix laying and chip sealing. In hot-mix laying, the mixture of a binder (coal tar, bitumen or a blended product containing both) and aggregate (stone chips) is spread on the roadway by a paving machine, followed by a roller. In the chip-sealing process (also known as surface dressing), the liquid binder (coal tar, bitumen, or a mixture of the two) is sprayed directly onto the road surface, then the aggregate stone is spread on top and rolled ([Darby et al., 1986](#)).

Detailed information on cessation of coal-tar use in the European paving industry has been collected in the course of an IARC study on cancer mortality among asphalt workers. [Table 1.2](#) presents the last reported year-of-use of coal tar in paving by any company that participated in the cohort study. The data originated from a company questionnaire and its ensuing evaluation by country-specific experts ([Burstyn et al., 2003](#)). A gradient in cessation of use can be seen, with Scandinavian countries ending use earlier than central and southern European countries, such as the Netherlands, France and Germany. However, even within countries, large differences in the use of coal tar have occurred between companies, depending on the supplier of the asphalt mixes and the presence of coke ovens in the neighbourhood. Even after cessation

**Table 1.2 Cessation of use of coal tar in asphalt paving (surface dressing)**

Country	Last year of use
Finland	1965
Denmark	1974
Sweden	1974
Norway	1984
the Netherlands	1990
France	1992
Germany	1995

From [Burstyn et al. \(2003\)](#)

of the use of coal tar, workers in road paving have continued to be exposed to this substance due to the use of recycled coal-tar asphalt in some countries.

## 2. Cancer in Humans

In *IARC Monograph Volume 92* ([IARC, 2010](#)) it was concluded that there is *sufficient evidence* in humans for the carcinogenicity of occupational exposures during paving and roofing with coal-tar pitch. This was based on studies of pavers and roofers who presumably had been exposed to coal-tar pitch (and often also to bitumen), which suggested increased cancer risks in these occupations. An excess risk for lung cancer was reported in studies of members of a roofer's union in the USA, in analyses of registry-based data on pavers in the United Kingdom and roofers in the USA, and in follow-up studies of cancer incidence among pavers in Finland and the Netherlands ([Kennaway & Kennaway, 1947, 1951](#); [Hammond et al., 1976](#); [Milham, 1982](#); [Pukkala, 1995](#); [Swaen & Slangen, 1997](#); [Stern et al., 2000](#)). An increased mortality from urinary bladder, laryngeal or skin (non-melanoma) cancer was observed in one or more of these cohorts, but this finding was not widely supported by other studies. In three case-control studies conducted in the USA, a tobacco-smoking-adjusted increase in the risk for lung

cancer was reported among roofers ([Schoenberg et al., 1987](#); [Zahm et al., 1989](#); [Morabia et al., 1992](#)) however, none of these increases was statistically significant. A meta-analysis of the case-control studies reported a statistically significant meta-relative risk ([Partanen & Boffetta, 1994](#)).

Since the previous evaluation ([IARC, 2010](#)) a few additional studies have been published with information on paving with coal-tar pitch and associated cancers.

## 2.1 Cohort Studies

Roofing and flooring, and paving of roads involve the use of bitumen and coal-tar pitch. Although coal-tar pitch has been phased out in most countries, some studies published since the previous *IARC Monograph* ([IARC, 2010](#)) have included workers in road-paving exposed to both petroleum-based bitumen and coal-tar pitch.

In studies in France, Norway, and Sweden a higher lung cancer mortality or incidence was found among workers first employed while the asphalt mixes still contained some coal tar (before 1970 in France and before 1965 in Norway and Sweden). None of the elevated rates were statistically significant ([Bergdahl & Järholm, 2003](#); [Randem et al., 2003](#); [Stücker et al., 2003](#)). In the French study a higher but statistically non-significant mortality from stomach cancer was found in workers hired before 1970 ([Stücker et al., 2003](#); see Table 2.1, available at <http://monographs.iarc.fr/ENG/Monographs/vol100F/100F-12-Table2.1.pdf>).

In a study in Finland road-paving workers were ranked by coal-tar exposure (see Table 2.1 on-line). Relative to those not exposed to coal tar, the risk for lung cancer was 1.49 for workers exposed to very low level of coal tar (assessed semiquantitatively on the basis of score-years) and 10.7 for those who exposed to intermediate levels of coal tar (p for trend = 0.05) ([Kauppinen et al., 2003](#)).

Bladder-cancer incidence by estimated average and cumulative benzo[a]pyrene exposure levels was evaluated in paving cohorts from Denmark, Finland, Israel, and Norway (see Table 2.1 on-line). An internal comparison showed indications of a trend with average exposure to benzo[a]pyrene (*P* for trend not significant) ([Burstyn et al., 2007](#)). The overall incidence of bladder cancer in European asphalt workers was similar to that expected (SMR 1.05; [Boffetta et al., 2003](#)).

## 3. Cancer in Experimental Animals

Six coal-tar pitches and three extracts of coal-tar pitches all produced skin tumours, including carcinomas, when applied to the skin of mice. An extract of roofing-tar pitch had both initiating and promoting activity in separate experiments ([IARC, 1985](#)).

## 4. Other Relevant Data

### 4.1 Mechanistic considerations relevant to the cancer hazards from exposure during roofing and paving with coal-tar pitch

#### 4.1.1 Experimental systems

In previous *IARC Monographs* ([IARC, 1985, 1987](#)) short-term tests to assess the genotoxicity of coal-tar pitch were reviewed. Coal-tar pitch and roofing-tar emissions were mutagenic in bacteria in the presence of an exogenous metabolic activation system, and in mammalian cells with and without metabolic activation. These agents also induced sister chromatid exchange in Chinese hamster ovary cells and enhanced viral transformation in Syrian hamster embryo cells,



both in the absence and presence of an exogenous metabolic activation system.

Chemical analyses of high-temperature coal-tar pitches identified several polycyclic aromatic hydrocarbons that are genotoxic and carcinogenic in experimental studies ([IARC, 1985](#)). These include benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, dibenz[*a,h*]anthracene, chrysene, and indeno[1,2,3-*cd*]pyrene ([IARC, 1983, 2010](#)). These polycyclic aromatic hydrocarbons may contribute to the genotoxic and tumorigenic activities of coal-tar pitches.

#### 4.1.2 Humans

DNA strand-breaks (measured by single-cell gel electrophoresis; comet assay) and the 8-oxo-deoxyguanosine/deoxyguanosine (8-oxo-dG/dG) ratio (measured by means of HPLC with electrochemical detection) were determined in peripheral blood leukocytes of roofers exposed to dust from coal-tar pitch (coal tar) during removal of existing roofs before applying hot asphalt. When the workers were stratified by 1-hydroxypyrene excretion in the urine, the amount of DNA strand-breaks in their leukocytes increased, and the 8-oxo-dG/dG ratio decreased in a dose-dependent manner ([Toraason et al., 2001](#)).

## 4.2 Synthesis

There is strong evidence from experimental data that coal-tar pitch has a genotoxic mechanism of action. There is moderate evidence in humans for a genotoxic mechanism underlying the effects of exposures during roofing and paving with coal-tar pitch, based on one study.

## 5. Evaluation

There is *sufficient evidence* in humans for the carcinogenicity of coal-tar pitch as encountered in paving and roofing. Coal-tar pitch as encountered in paving and roofing causes cancer of the lung.

Also, a positive association has been observed between exposure to coal-tar pitch as encountered in paving and roofing, and cancer of the bladder.

There is *sufficient evidence* in experimental animals for the carcinogenicity of coal-tar pitch.

There is strong evidence from experimental data that coal-tar pitch has a genotoxic mechanism of action. There is moderate evidence in humans for a genotoxic mechanism underlying the effects of exposures during roofing and paving with coal-tar pitch, based on one study.

Coal-tar pitch is *carcinogenic to humans* (Group 1).

## References

- Bergdahl IA & Järholm B (2003). Cancer morbidity in Swedish asphalt workers. *Am J Ind Med*, 43: 104–108. doi:10.1002/ajim.10157 PMID:12494427
- Betts WD (1997) *Tar and pitch*. In: *Kirk-Othmer Encyclopedia of Chemical Technology*, 5th ed. New York: John Wiley & Sons
- Boffetta P, Burstyn I, Partanen T et al. (2003). Cancer mortality among European asphalt workers: an international epidemiological study. I. Results of the analysis based on job titles. *Am J Ind Med*, 43: 18–27. doi:10.1002/ajim.10181 PMID:12494418
- Burstyn I, Boffetta P, Kauppinen T et al. (2003). Estimating exposures in the asphalt industry for an international epidemiological cohort study of cancer risk. *Am J Ind Med*, 43: 3–17. doi:10.1002/ajim.10183 PMID:12494417
- Burstyn I, Kromhout H, Johansen C et al. (2007). Bladder cancer incidence and exposure to polycyclic aromatic hydrocarbons among asphalt pavers. *Occup Environ Med*, 64: 520–526. doi:10.1136/oem.2006.029801 PMID:17332134
- Darby FW, Willis AF, Winchester RV (1986). Occupational health hazards from road construction and sealing

- work. *Ann Occup Hyg*, 30: 445–454. doi:10.1093/annhyg/30.4.445 PMID:3813349
- Hammond EC, Selikoff IJ, Lawther PL, Seidman H (1976). Inhalation of benzpyrene and cancer in man. *Ann N Y Acad Sci*, 271: 1 Neoplasia in116–124. doi:10.1111/j.1749-6632.1976.tb23100.x PMID:1069493
- IARC (1987). Overall evaluations of carcinogenicity: an updating of IARC Monographs volumes 1 to 42. *IARC Monogr Eval Carcinog Risks Hum Suppl*, 7: 1–440. PMID:3482203
- IARC (1983). Polynuclear aromatic compounds, Part 1, chemical, environmental and experimental data. *IARC Monogr Eval Carcinog Risk Chem Hum*, 32: 1–453. PMID:6586639
- IARC (1985). Polynuclear aromatic compounds, Part 4, bitumens, coal-tars and derived products, shale-oils and soots. *IARC Monogr Eval Carcinog Risk Chem Hum*, 35: 1–247. PMID:2991123
- IARC (2010). Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. *IARC Monogr Eval Carcinog Risks Hum*, 92: 1–853. PMID:21141735 PMID:18756632
- IPCS (2004). *Asphalt (Bitumen)*. (Concise International Chemical Assessment Document 59), Geneva: International Programme on Chemical Safety, WHO
- Kauppinen T, Heikkilä P, Partanen T *et al.* (2003). Mortality and cancer incidence of workers in Finnish road paving companies. *Am J Ind Med*, 43: 49–57. doi:10.1002/ajim.10161 PMID:12494421
- Kennaway EL & Kennaway NM (1947). A further study of the incidence of cancer of the lung and larynx. *British Journal of Cancer*, 1: 260–298.
- Kennaway EL & Kennaway NM (1951). Studies of the incidence of cancer of the lung and larynx. *British Journal of Cancer*, V: 153–158.
- McClellan MD, Rinehart RD, Sapkota A *et al.* (2007). Dermal exposure and urinary 1-hydroxypyrene among asphalt roofing workers. *J Occup Environ Hyg*, 4: Suppl 1118–126. doi:10.1080/15459620701334756 PMID:17503278
- Milham S (1982) *Occupational Mortality in Washington State 1950–1979*, Prepared under Contract No. 210–80–0088, Cincinnati, OH, National Institute for Occupational Safety and Health.
- Morabia A, Markowitz S, Garibaldi K, Wynder EL (1992). Lung cancer and occupation: results of a multi-centre case-control study. *Br J Ind Med*, 49: 721–727. PMID:1419861
- NIOSH (2000) National Institute for Occupational Safety and Health. *Health Effects of Occupational Exposure to Asphalt*. Hazard Review
- Partanen T & Boffetta P (1994). Cancer risk in asphalt workers and roofers: review and meta-analysis of epidemiologic studies. *Am J Ind Med*, 26: 721–740. doi:10.1002/ajim.4700260602 PMID:7892824
- Pukkala (1995). *Cancer Risk by Social Class and Occupation*, Vol. 7, *Contributions to Epidemiology and Biostatistics*, Basel, Karger.
- Randem BG, Langård S, Dale I *et al.* (2003). Cancer incidence among male Norwegian asphalt workers. *Am J Ind Med*, 43: 88–95. doi:10.1002/ajim.10169 PMID:12494425
- Schoenberg JB, Stemhagen A, Mason TJ *et al.* (1987). Occupation and lung cancer risk among New Jersey white males. *J Natl Cancer Inst*, 79: 13–21. PMID:3474440
- Stern FB, Ruder AM, Chen G (2000). Proportionate mortality among unionized roofers and waterproofers. *Am J Ind Med*, 37: 478–492. doi:10.1002/(SICI)1097-0274(200005)37:5<478::AID-AJIM4>3.0.CO;2-8 PMID:10723042
- Stücker I, Meguellati D, Boffetta P *et al.* (2003). Cohort mortality study among French asphalt workers. *Am J Ind Med*, 43: 58–68. doi:10.1002/ajim.10140 PMID:12494422
- Swaen GM & Slangen JM (1997). Mortality in a group of tar distillery workers and roofers. *Int Arch Occup Environ Health*, 70: 133–137. doi:10.1007/s004200050197 PMID:9253642
- Toraason M, Hayden C, Marlow D *et al.* (2001). DNA strand breaks, oxidative damage, and 1-OH pyrene in roofers with coal-tar pitch dust and/or asphalt fume exposure. [Erratum in: *Int Arch Occup Environ Health* 2002] *Int Arch Occup Environ Health*, 74: 396–404. doi:10.1007/s004200100238 PMID:11563602
- Zahm SH, Brownson RC, Chang JC, Davis JR (1989). Study of lung cancer histologic types, occupation, and smoking in Missouri. *Am J Ind Med*, 15: 565–578. doi:10.1002/ajim.4700150509 PMID:2741962