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## Carcinogenic Risks in Working with Oxidized Bitumen



**Title:**

Carcinogenic Risks in Working with Oxidized Bitumen

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October 2014

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## 1. Abstract

In its report "Bitumens and Bitumen emissions, and some N- and S- Heterocyclic Polycyclic Aromatic Hydrocarbons" (1), the International Agency for Research on Cancer (IARC) has addressed the risk of cancer associated with jobs involving various types of bitumens.

According to IARC, tests have shown that the higher the bitumen temperature, the more intense the emissions and the heavier the Polycyclic Aromatic Hydrocarbons (PAH)s that are released. Carcinogenicity has been observed in parallel with this in testing involving animals exposed to emissions from oxidized bitumens that has been heated to over 199°C, which corresponds to the temperatures to which oxidized bitumen is heated in connection with roofing work. Carcinogenicity caused by oxidized bitumens heated to 175°C, which corresponds to the maximum material temperature encountered when laying asphalt on roads, has not been demonstrated.

In the report, IARC points out that roof-layers will typically be exposed to higher levels of bitumen than will asphalt workers, due to the higher temperature to which roofing bitumen is heated. The Danish Working Environment Authority's guidelines (7) for work involving roofing felt containing oxidized bitumen state that such work should not be carried out at bitumen temperatures in excess of 230°C. Work involving asphalt with an admixture of oxidized bitumen is performed at material temperatures roughly 50°C lower, i.e. 175°C- 180°C, and will consequently be in compliance with the applicable working environment regulations. Because the amount of oxidized bitumen from crushed roofing felt material (BitumenMix) will, at the same time, account for only 19% of the total amount of bitumen in the asphalt, emissions of carcinogenic substances from the oxidized bitumen will be relatively low.

Based on the studies cited in this memorandum, there is thus neither evidence for nor any indication that the use of oxidized bitumen in the form of crushed roofing felt in hot-mix asphalt will, within the normal temperatures at which hot-mix asphalt is laid (<180°C), entail significantly greater health risks than work involving asphalt containing virgin road bitumen.

## 2. Introduction and background

In 2013, IARC published the "Bitumens and Bitumen emissions, and some N- and S- Heterocyclic Polycyclic Aromatic Hydrocarbons" (1) report concerning the risk of developing cancer associated with work involving various types of bitumens.

Based on their review of studies conducted to date, IARC has chosen to *change the risk of developing cancer associated with work involving class 2 bitumen (oxidized bitumens, i.e. both oxygenated and deaerated bitumens) in connection with roofing work from category 2b (possibly carcinogenic) to 2a (probably carcinogenic).*

The significance of this classification and its impact on work involving oxidized bitumen in the form of crushed roofing felt for road-building applications are unclear and, in view of this, Tarpaper Recycling ApS has asked the Danish Technological Institute to prepare a memorandum to address these issues.

The present memorandum has been prepared based on the available literature, and on interviews with relevant experts.

### **3. What is oxidized bitumen?**

"Oxidized bitumen" is a collective term for bitumens that have air blown through them during their manufacturing process, with the result that they become highly oxidized. The oxygen in the air reacts chemically with the resins present in bitumen, transforming them into asphalts via oxidation, which in practical terms entails a hardening of the material. This collective term covers two types, i.e. semi-blown bitumen and blown bitumen. The semi-blown bitumens are typically softer bitumens that are hardened for, e.g. road-building applications. This is achieved by oxidizing them for a shorter time, cf. the description above. The blown bitumens are typically made for roofing applications (roofing felt) and manufactured using a significantly longer oxidizing period than the semi-blown bitumens.

In theory, all bitumen used should fall under the term "oxidized bitumen", as this process occurs autonomously, only significantly more slowly than when forced. The bitumen contained in asphalt paving is also oxidized via interaction with the oxygen in the air, but the bitumens that are oxidized naturally are typically referred to as "hardened bitumen" in order to differentiate between the different products.

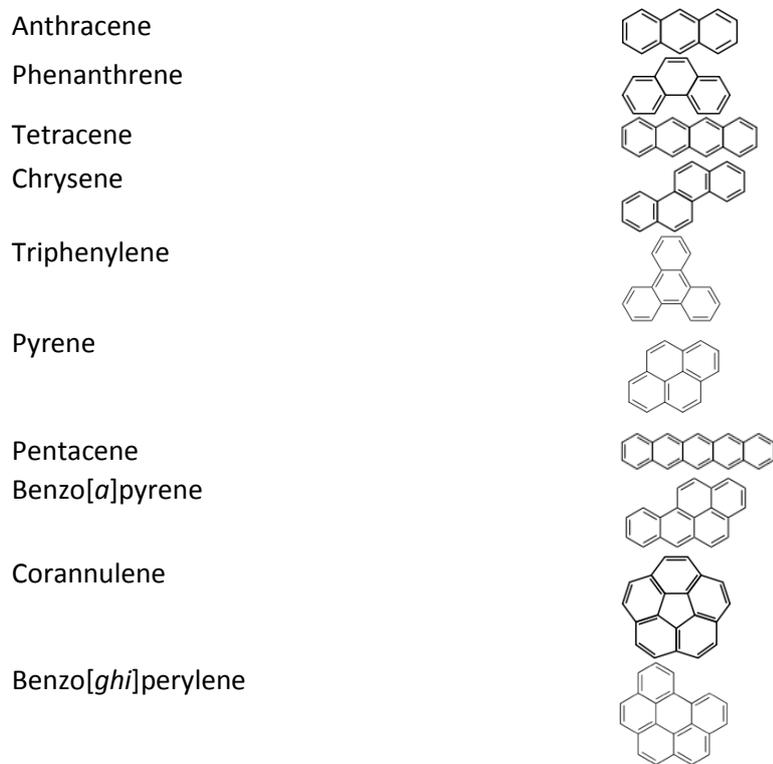
Bitumen that is not oxidized via oxygenation in the manufacturing process and that is used in pavements is often called "road bitumen" or "straight-run bitumen".

#### **PAHs in bitumen**

PAHs are mutagenic substances that are suspected of being carcinogenic in animals and man, and they have been focused on as an environmental problem for several decades because of their unhealthy properties (2). Coal tar, soot and mineral oil are considered to be carcinogenic in humans, and in this context benzo(a)pyrene (BaP) has been the subject of countless studies. BaP has been documented as a highly potent carcinogen. A number of other PAHs have also been documented as carcinogens and, because there are many different substances in products that contain PAHs, it is often unclear whether the effects are attributable to simultaneous exposure to these carcinogenic PAHs or to other substances that have not been studied.

The occupational risk associated with exposure to bitumen fumes is often characterized by measuring the proportion of PAH components with 3-6 aromatic rings in the aerosol phase (3).

Examples of PAHs with 3-6 rings include:



Bitumen (petroleum oil hydrocarbons) contains very little in terms of (carcinogenic) PAHs, as most of them are removed during the production of bitumen, although PAHs with 2 and up to 7 aromatic rings may still be present. The content of PAHs in oxidized bitumen compared to non-oxidized bitumen is 10-30% lower, due to the oxidizing process (4). This is supported by Trumbore et al. (5), whose citation in the IARC report (1) states that oxidizing bitumen results in fewer PAHs with 4-6 aromatic rings. According to (3) and (4), it is specifically the 4-6 ring PAHs that are the most carcinogenic. However, the oxidizing process is often accelerated by adding flux oils. These flux oils have a side effect in that the content of PAHs, particularly those with 4-6 aromatic rings, increases by a factor of up to three compared with oxidized bitumens to which no flux oils have been added.

#### 4. IARC's classification method and Danish Working Environment Authority's working environment limit values

In their classification process, IARC rates substances based on the extent to which they are or are not hazardous to health. The classes to which substances are assigned depend on the strength of the evidence that they are carcinogenic upon exposure, and not on the extent of their potential for exposure. As a result, no risk-based analysis is performed, in which an assessment is made as to how hazardous to health a substance is in combination with occupational exposure to the substance in question in each individual situation.

IARC classifies the carcinogenicity of substances using the following scale:

- Group 1: Carcinogenic substances
- Group 2A: Probably carcinogenic exposures
- Group 2B: Possibly carcinogenic
- Group 3: Non-classifiable based on the carcinogenic effect of the substance on humans
- Group 4: Probably non-carcinogenic for humans

Clear and reliable epidemiological studies and evidence must be present as the basis for classifying a substance as belonging to Group 1.

Groups 2A and 2B are close neighbours. Substances are assigned to Group 2A when there is an indication of evidence from epidemiological studies and comprehensive evidence from animal studies.

Substances are assigned to Group 2B when there is an indication of evidence from epidemiological studies but the evidence from animal studies is not comprehensive. Substances are also assigned to this group when there is insufficient evidence from epidemiological studies or no human data, but comprehensive evidence from animal studies is present. Assignment to Group 2A requires an effect on at least two different animal species or phyla, while the absence of the necessary animal studies (6) constitutes grounds for assignment to Group 2B.

Substances that cannot be assigned to other groups are put in Group 3, which covers substances for which no or insufficient data are available.

In view of the foregoing, IARC thus classifies the carcinogenicity, rather than the degree of risk of being exposed to carcinogenic substances in a work situation.

Degree of risk = **carcinogenicity** x exposure

*The Danish Working Environment Authority* has formulated guidelines for working with asphalt materials based on a risk assessment. These guidelines include working environment limit values in the form of maximum temperatures at which work involving bitumen products can be done. An excerpt from the guidelines is provided below.

Materials/processes	Coating type	Max. use temperature	Bitumen type
Road asphalt	Surface treatment	90°C	B 50 - B 500
	Surface treatment	150°C	B 100 - B 200
	Surface treatment	190°C	B 300 - B 700
	Powdered asphalt	160°C	B 300 - B 500
	Asphalt concrete, ABS and SMA	185°C	B 45 - B 180
	Gravel asphalt concrete	180°C	B 60 - B 85
	Recycled	190°C	B 45 - B 700
	Asphalt concrete with modified bitumen	190°C	K and R 35-90

Roof covering	Oxidized bitumen	230°C	B 115/15 - B 95/35
Bridge insulation etc.	Bridge insulation	Max. 250°C	

List of maximum use temperatures in relation to bitumen types (7)

In the table above, the Danish Working Environment Authority assesses the extent to which there is a risk of being exposed to carcinogenic substances, i.e. the temperatures at which various types of bitumen can be handled safely.

**Degree of risk** = carcinogenicity x exposure

## 5. Exposure

PAHs are released into the air when bitumen is heated. IARC (1) notes that the physical/chemical properties of the individual constituents of bitumen entail that the composition and physical form of the emissions from heated bitumen will depend on the temperature to which the bitumen is heated. Tests using condensate have clearly shown that temperature has a major impact on the carcinogenicity of the bitumen fumes (1).

Cavallari et al. (8) report that when straight-run bitumen (road bitumen) is heated to between 120°C and 150°C, the emissions will contain PAHs with 2-3 rings and, to a much lesser extent, those with 4-6 rings. The frequency of release and concentration of PAHs with 4-6 rings increase when the bitumen is further heated to between 180°C and 230°C, which corresponds to the temperature at which work is done when welding roofing felts. Multivariate analysis has also shown that the amount of PAHs increases with increasing temperature, and that this effect is more pronounced for oxidized bitumen than for straight-run bitumens (8).

IARC's report is based on animal studies. The animals were exposed to emissions from oxidized bitumens dissolved in fluid applied to their skin. The emissions were obtained from oxidized bitumen heated to temperatures of 175°C, 199°C, 232°C and 316°C. No evidence of carcinogenicity from oxidized bitumens heated to 175°C has been reported while, on the other hand, carcinogenicity has been demonstrated at temperatures of 199°C, 232°C and 316°C. According to IARC, animal studies involving the inhalation of emissions from oxidized bitumens have not shown carcinogenic effects (1).

Generally speaking, asphalt fumes generated in field studies exhibit low genotoxicity, while asphalt fumes generated in laboratories are mutagenic, and produce DNA adducts. Temperatures higher than those associated with the laying of asphalt are used in the laboratory tests. Painting asphalt on the skin of test animals has resulted in local tumours, but no corresponding reactions have been reported in humans. An increased incidence of lung cancer has been seen in humans, but the extent to which they are affected by confounders (coal tar in recycled asphalt, smoking, quartz and diesel exhaust) is unclear.

### Temperature conditions in working with various bituminous products

Roofing felt and shingels can contain oxidized bitumen. Oxidized bitumen is still being used today, but there is a clear trend toward using polymer-modified bitumen instead. When installing roofing felt, the felt is either heated directly, e.g. by heating the underside with a flame, or by spraying a heated bitumen emulsion onto the surface on which the roofing felt is to be laid. In roofing work, the bitumen is heated to a working temperature of between 180°C and 230°C.

In the factory production of asphalt, bitumen is heated to a maximum of 180°C (hot-mix). While it is being laid, the temperature of the asphalt will be between 110°C and 170°C, depending on the type of asphalt, the mode of transport, the distance to the laying site, and the weather. Generally speaking, the bitumen temperature level is markedly lower during the production and laying of asphalt than in connection with the welding of roofing felt.

IARC points out that roof-layers are typically exposed to higher bitumen emissions than are asphalt workers, due to the higher working temperature of the bitumen (1).

### Amount of oxidized bitumen from crushed roofing felt in asphalt production

On average, a bitumen percentage of roughly 55% is reached during the production of BitumenMix. BitumenMix consists of new and old roofing felt. New roofing felt material contains roughly 20-30% oxidized bitumen (9). The older the roofing felt, the more oxidized bitumen it can be expected to contain. Polymer-modified roofing felt was introduced in the mid-1980s. Roofing felt produced before then may be expected to contain up to 100% oxidized bitumen.

Assuming the production one tonne of asphalt with a bitumen content of 5%:

- 2% (20 kg) of bitumen will derive from BitumenMix, corresponding to 40% of the total amount of bitumen.
- the total amount of oxidized bitumen will be roughly 19% in relation to the total amount of bitumen in one tonne of asphalt.

## 6. Summary and closing comments

In its report "Bitumens and Bitumen emissions, and some N- and S- Heterocyclic Polycyclic Aromatic Hydrocarbons" (1), IARC has addressed the risk of cancer associated with jobs involving various types of bitumens.

Based on their review of studies conducted to date, IARC has chosen to change the risk of developing cancer associated with work involving oxidized bitumens *in connection with roofing work* from category 2b (possibly carcinogenic) to 2a (probably carcinogenic).

According to IARC, tests have shown that the higher the bitumen temperature, the more intense the emissions and the heavier the PAHs that are released. Emissions of PAHs in connection with the laying of asphalt on roads will consequently not be nearly as intense or concentrated as those

associated with welding roofing felt. IARC also confirms that carcinogenicity has been reported in studies involving animals exposed to emissions from oxidized bitumens heated to over 199°C, which corresponds to the temperatures to which oxidized bitumen is heated during roofing work. Carcinogenicity has not been demonstrated in connection with oxidized bitumens heated to 175°C, which corresponds to the maximum material temperature associated with the laying of asphalt on roads.

In their report, IARC points out that roof layers will typically be exposed to larger amounts of emissions from bitumen than will asphalt workers, due to the higher temperature to which the bitumen is heated. This is consistent with the Working Environment Authority's guidelines (7), which state that work with roofing felt containing oxidized bitumen should be carried out at bitumen temperatures no higher than 230°C. Work with asphalt with an admixture of oxidized bitumen is carried out at temperatures that are roughly 50°C lower, i.e. 175°C-180°C, and will consequently be in compliance with the applicable working environment regulations. Because the amount of oxidized bitumen from crush roofing felt materials, i.e. BitumenMix, will at the same time comprise only 19% of the total amount of bitumen in the asphalt, emissions of carcinogenic substances from the oxidized bitumen will be relatively low.

Based on the foregoing, we do not consider it reasonable to equal the risk of developing cancer associated with laying asphalt containing crushed roofing felt with the risk associated with welding roofing felt.

## 7. References

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