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ENVIRONMENTAL SCAN 232

ISCRR
Institute for Safety, Compensation and Recovery Research

Bitumen contents and fumes

Health effects associated with exposure to bitumen

An Environmental Scan of the asphalt industry on health risks associated with exposure to bitumen contents and fumes.

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A joint initiative of WorkSafe VICTORIA and MONASH University

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ABBREVIATIONS

CAS	Chemical Abstracts Service Registry Number
HMA	Hot mix asphalt
HSR	Health and Safety Representative
MSDS	Material Safety Data Sheet
NATA	National Association of Testing Authorities
OHS	Occupational Health and Safety
PAH	Polycyclic Aromatic Hydrocarbon
PPE	Personal protective equipment
TVL	Threshold Value Limit
WMA	Warm mix asphalt

EXECUTIVE SUMMARY

Background

Under normal ambient conditions, bitumen is stable, solid and does not present any health risks. However, most bitumen applications are carried out at high temperatures between 170°C and 180°C, and heated bitumen produce 'emissions', which comprise a complex mixture of vapours, aerosols, gases and particulate matter. As a result of exposure to fuming loads or contact with bitumen products, WorkSafe has received reports of employees experiencing acute health effects such as dizziness, nausea and respiratory discomfort.

Purpose

The key questions were:

1. What is the bitumen and asphalt industry profile, e.g. sources, types and road paving crew work conditions, in the Victorian context?
2. What adverse health effects have been associated with exposure to bitumen contents and fumes in the course of road construction and/or repairs?
3. What factors are shown to mitigate the risk of, or protect workers from exposure to, bitumen contents and fumes during road construction and repairs?

Approach

This Environmental Scan comprised two approaches:

- Worldwide desktop scan – publicly available online resources from asphalt companies, government institutions and research agencies, nationally and internationally, were reviewed between December 2018 and January 2019 to identify information and materials related to bitumen fumes. Workers' compensation agencies in Australia were also contacted.
- Key informant interviews – six interviews were conducted with general managers / regional managers / business development managers and an occupational hygienist from asphalt companies, as well as a representative from the Australian Workers' Union (AWU).

This Environmental Scan was part of a larger stream of work on Bitumen Contents and Fumes (ISCRR project 232) and should be considered with other evidence such as the other component of this project, the Evidence Review of scientific peer-reviewed literature.

Key findings

Industry profile

- Australia primarily imports bitumen from South Korea, Singapore and Thailand. Viva Energy's Geelong refinery is the only Australian manufacturer of bitumen.
- Conventional or 'straight-run' bitumen is most commonly used. Polymer modified binders, where either synthetic polymers or crumb rubber is added, are used if requested.
- Hot mix asphalt (HMA) is used widely in Australia, largely driven by the regulatory requirements and standards for most road works projects. HMA, which is applied at about 170°C to 180°C, has been associated with fuming issues.
- Paver operators and screed operators are more exposed to bitumen fumes compared to other job taskers such as roller drivers and rakers.

- To clean paving equipment, two asphalt companies have switched from diesel to organic-based and biodegradable products while the other two stated they were using and trialling a few different products, including diesel.

Acute health effects

- Bitumen fume exposure has been associated with acute health effects such as eye, nose, throat and skin irritation, nausea and respiratory discomfort.
- Asphalt companies suggested acute health effects related to fuming loads are random and reported that they are very responsive to events if/when they occur.
- This is in contrast to survey results from paving workers showed that acute health effects related to fuming loads are common.
- Under-reporting of events is a significant problem, due to worker characteristics, desire to get the job finished, fear of reprisals and perceived lack of response from management.

Chronic health effects

- IARC concluded that occupational exposures to straight-run bitumens and their emissions during road paving are 'possibly carcinogenic to humans' (Group 2B).
- Asphalt companies did not have anything conclusive to show risk of any chronic illness to workers over constant bitumen exposure and the report on Tasmanian Bitumen Workers Issues was unable to provide a clear picture on longer-term effects from bitumen exposure.
- Data from the AWU survey of workers revealed that 76% of workers were concerned about the long-term effects of exposure to bitumen fuming.

Fume monitoring and testing

- Asphalt companies engage with NATA-accredited laboratories to carry out independent testing such as job site monitoring and personal monitoring. To date, results showed that all measures of exposure to bitumen fumes and contents were within accepted limits.
- AWU suggested that testing needs to be reviewed and more investigations needed to identify what is making the workers unwell, as 132 out of 152 surveyed workers reported having experienced one or more conditions or symptoms after exposure to bitumen fumes.
- One asphalt company is redeveloping a more comprehensive biological monitoring system (e.g. bitumen metabolite testing and urine testing) for their road paving crews across all Australian states, by doing a full exposure assessment on each of the different bitumen products they use.

Risk Management

- Occupational exposure limits for bitumen emissions vary in numerical values and methods of evaluation around the world.
- Safe Work Australia has specified an exposure standard for bitumen fumes (CAS# 8052-42-4) at 5mg/m^3 in an 8-hour time-weighted average.
- All asphalt companies reported that they had various preventive measures against excessive fuming and responsive measures in the event of excessive fuming: engineering controls, operational checks, reporting channels, employee medical checks, safety culture and personal protective equipment (PPE).
- AWU emphasized the need for better reporting from road paving crews about their concerns and launched an "Asphalt Reporting App and Hotline" in October 2018.

- Warm mix asphalt (WMA) is used increasingly as a replacement for traditional hot mix asphalt (HMA) in many countries. It requires lower production and laydown temperatures, typically by 20–50°C, compared with conventional HMA, and therefore produces fewer vapours and aerosols, amongst other benefits.
- Although the asphalt companies interviewed stated that they are technologically-ready to supply WMA, they suggested that WMA is currently not used widely in Australia due to insufficient awareness among clients and current specifications by state governments.

Insights and implications

Acute health effects as a result of exposure to bitumen fumes have been reported. A large proportion of workers have experienced these symptoms, however asphalt companies stated that there were only odd cases. This discrepancy could be due to a lack of reporting by workers and failure to test for the 'right' hazardous substances by companies. Findings on chronic health effects from bitumen fumes are inconclusive, although 76% of road paving workers in an AWU survey indicated they were concerned for their long-term health.

It would therefore be prudent to continue to promote good occupational safety and hygiene practices, as well as continuous improvement in engineering controls, such as efficient fume extraction systems. Strengthening the reporting culture would be valuable for capturing data to inform risk mitigation strategies and improving the understanding of bitumen fumes effects.

Considerations for the bitumen and asphalt industry:

- More Health and Safety representatives (HSR) to be appointed and trained in road paving crews.
- Review the criteria for testing to improve hazardous substance testing.
- A more standardized form of fume monitoring.
- More understanding and investigation in the use of crumb rubber asphalt in the Australian context.
- Explore the possibilities of using WMA more widely in Victoria and Australia.
- More consultation and sharing among stakeholders, especially with the road paving crews.

1. INTRODUCTION

1.1 Introduction

Victoria is undergoing substantial long-term road repair, construction and infrastructure works. In recent months, there have been concerns raised in regards to the composition, nature and risk profile of bitumen loads that have been delivered to various road infrastructure worksites around Victoria.

The manufacture of asphalt is carried out by mixing heated, dry gravel with 4-5% hot bitumen, which is a petroleum-derived binding agent. Heated bitumen enables the asphalt to flow effectively, and spread onto the road surface. Ambient temperature bitumen is non-volatile. However, heated bitumen produces emissions, which comprise a complex mixture of vapours, aerosols, gases, and particulate matter.

WorkSafe Victoria has received several complaints and service requests involving 'fuming loads', and has responded to these. The fuming phenomenon, which looks similar to steam, occurs in some instances as a result of elevated temperature of asphalt loads. As a result of exposure to fuming loads or contact with bitumen products, employees have reported experiencing acute health effects such as dizziness, nausea and respiratory discomfort.

Worksafe Inspectors have visited various road construction workplaces and bitumen suppliers, with investigations made into the nature of the bitumen used including risk mitigation measures to ensure the health and safety of workers.

A prevention-led approach is one of the key objectives of the WorkSafe 2030 plan. It is expected that a durable and extensive research project into the bitumen fuming load issue will deliver a number of prevention initiatives to the industry. This may include practical information and guidance for workers directly affected by, or required to work with, these substances; and broader industry guidance to better understand the risks associated with heated bitumen products.

1.2 Purpose

This project has two components - an Evidence Review (ISCRR report 232-0219-R01) and an Environmental Scan of the asphalt industry on health risks associated with exposure to bitumen contents and fumes. This report contains findings from the Environmental Scan.

The approach taken for the Environmental Scan was to examine three key questions:

1. What was the bitumen and asphalt industry profile including sources, types and road paving crew work conditions, in the Victorian context?
2. What adverse health effects have been associated with exposure to bitumen contents and fumes in the course of road construction and/or repairs?
3. What factors are shown to mitigate the risk of, or protect workers from exposure to, bitumen contents and fumes during road construction and repairs?

The primary objective of the Environmental Scan was to identify risk factors for health effects associated with the asphalt industry, particularly those associated with the application of heated bitumen at roadside workplaces.

A secondary objective included identification of risk mitigation measures and related controls to minimise risks to road paving crew, and potentially provide a foundation for an industry state of knowledge to assist duty holders to meet their obligations under the OHS legislation.

1.3 Approach

The Environmental Scan is part of a larger stream of work on Bitumen Contents and Fumes (ISCRR project 232). It provides a snapshot of information on current and emerging practices in the area of bitumen contents and fumes in road paving works, using all reasonable efforts within the timelines. It is not an exhaustive account of all current and emerging practices in the sector and should be considered along with other evidence such as the Evidence Review.

This Environmental Scan included national and international sources of information and comprised two approaches:

- Worldwide desktop scan (online)
- Key informant interviews

For the desktop scan, local and international asphalt companies and government agency websites were reviewed between December 2018 and January 2019 to identify information and materials related to bitumen fumes. A scan of publicly available online resources, such as existing work and research in this area, policy and planning reports, industry standards, practices and trends, current and emerging government legislation and policies, was conducted. An Australian Workers' Union (AWU) survey information related to bitumen exposure from the perspective of asphalt workers was also examined. In total, 152 workers participated in this survey with 95% from Victoria.

Workers' compensation agencies in Australia were also contacted via email with New South Wales, Queensland and Tasmania identified as having carried out bitumen-related studies. Information most relevant to the scope of this Environmental Scan was a report on Tasmanian bitumen workers where 34 workers were interviewed. The report was released in 2005 by the then-Department of Infrastructure, Energy and Resources (now part of the Department of State Growth of Tasmania).

An overview of the responses received from workers' compensation agencies are provided in Table 1.

Table 1. List of contacted OHS and workers' compensation agencies in Australia

State	Agency	Response
New South Wales	SafeWork NSW	Hygiene and Toxicology Team and TestSafe Laboratories have, from time to time, investigated bitumen fumes, specifically looking at Poly Nuclear Aromatic Hydrocarbons (PNAHs or PAHs). This work has not been confined to the road paving industry but has covered tasks such as stripping bitumen sealants from potable water tanks and sealing roof areas of buildings such as residential flats and factories.
Queensland	Workplace Health and Safety QLD	An audit program of bitumen and asphalt plants on explosion and fire risks was conducted in 2016, but no research was carried out on bitumen fumes exposure on road workers.
Tasmania	Department of State Growth	A 'Report on Tasmanian bitumen workers issues' was released in 2005 by then-Department of Infrastructure, Energy and Resources.
Victoria	WorkSafe VIC	WorkSafe Victoria had meetings with AAPA and selected asphalt companies. Meeting notes provided.

Note: Australian Capital Territory, Northern Territory, South Australia and Western Australia were contacted but no information was provided within the timeframe of this project.

For the key informant interviews, nine organisations were contacted and, of these, five organisations accepted. Altogether, six interviews were conducted with general managers, regional managers, business development managers and an occupational hygienist from four asphalt companies (de-identified for this report) as well as a representative from the AWU. Two organisations also elected to share additional information and materials via email. The format of the interview was semi-structured to determine the level of awareness among the identified organisations, their current practices and OHS measures in relation to bitumen fumes management.

An overview of the organisations included in the desktop scan and the approach to collating information is provided in Table 2.

Table 2. Organisations included in the desktop scan

Organisation	Nature of organisation	Country	Desktop scan	Information / materials provided
Australian Asphalt Pavement Association (AAPA)	Industry association	Australia	✓	✓
Australian Institute of Occupational Hygienists (AIOH)	Professional association of occupational hygienists	Australia	✓	
Australian Road Research Board (ARRB)	Research agency for state road agencies and communities	Australia	✓	
Australian Workers Union (AWU)	Union	Australia	✓	✓
AustRoads	Peak organisation of Australasian road transport and traffic agencies	Australia	✓	
Breathe Freely	Industry peak body	UK	✓	
Colas	Asphalt company	France	✓	
Concawe	Research institute by a group of leading oil companies, a division of the European Petroleum Refiners Association	Europe	✓	
Department of State Growth TAS	State government agency	Australia	✓	✓
French Agency for Food, Environmental and Occupational Health & Safety (ANSES)	Government research agency	France	✓	
French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS)	A non-profit organisation created under the aegis of national social security scheme	France	✓	
German Bitumen Forum	A consortium of institutions / stakeholders in the bitumen industry	Germany	✓	

Organisation	Nature of organisation	Country	Desktop scan	Information / materials provided
Health and Safety Executive (HSE)	Government agency	UK	✓	
International Agency for Research on Cancer (IARC)	Intergovernmental research agency in causes of cancer	International	✓	
National Asphalt Pavement Association (NAPA)	Industry association	US	✓	
National Institute for Occupational Safety and Health (NIOSH)	Governed by the Center for Disease Control and Prevention	US	✓	
Occupational Safety and Health Administration (OSHA)	An office within the US Department of Labor	US	✓	
Safework Australia	Government agency	Australia	✓	
Safework NSW	State workers' compensation agency	Australia	✓	✓
SAMI Technologies	Bitumen manufacturer	Australia	✓	
VicRoads	Victorian state road authority	Australia	✓	✓
Viva Energy	Bitumen manufacturer	Australia	✓	
Workplace Health and Safety QLD	State workers' compensation agency	Australia	✓	✓
WorkSafeBC	Workers' compensation board of British Columbia	Canada	✓	
WorkSafe New Zealand	Government agency	New Zealand	✓	
World Health Organization (WHO)	Specialised agency of the United Nations	International	✓	

2. FINDINGS: INDUSTRY PROFILE

Key messages

- Australia predominantly imports bitumen from refineries in South Korea, Singapore and Thailand.
  - Viva Energy's Geelong refinery is the only manufacturer of bitumen in Australia.
- There are two types of bituminous binders:
  - Conventional or "straight-run" bitumen is used most commonly, over 90%.
  - Polymer modified binders, where either synthetic polymers or crumb rubber is added.
- Three types of asphalt:
  - Hot mix asphalt (HMA), warm mix asphalt (WMA) and cold mix asphalt.
  - HMA is used most commonly (between 95-98%) by the asphalt companies interviewed, who reported that this is largely driven by the regulatory requirements and standards for most road work projects.
- Length of time road paving crew could be exposed to bitumen fumes:
  - According to asphalt companies, the road paving crew's potential exposure to bitumen fumes is between 2-5 hours of actual asphalt laying time per day (in an 8-10-hour shift).
  - Paver operators and screed operators more strongly exposed compared to other job taskers.
- Cleaning agent
  - To clean paving equipment, two asphalt companies have switched from diesel to organic-based and biodegradable products while another two stated they were using and trialling a few different products, including diesel.

2.1 Bitumen content and fumes

Under normal ambient conditions, bitumen is stable, solid and does not present any health risks. However, most bitumen applications are carried out at temperatures between 170°C and 180°C, at which point fuming and to a larger extent, aerosol release of bitumen may occur.

Various additives are added to make the mix more viscous or compressible. Australian asphalt companies are required to meet the standards and requirements set out by state bodies such as VicRoads. According to the asphalt companies interviewed, various state bodies have different specifications. Before a batch goes out the gate, samples are taken directly from the back of the truck and tests are done on the properties to ensure compliance. These could be carried out by industrial chemists and engineers on site or in a laboratory environment.

A comprehensive international review of bitumen emissions by IARC found that the asphalt composition varied substantially depending on the asphalt supplier and the type of road surface required. "Consequently, no two bitumen products are chemically identical"[(1)]

As such, bitumen and bitumen fumes and vapours vary depending upon the temperature, manufacturing process, presence of additives and modifiers, and work practices.[(2)] Bitumen emissions are complex. At temperatures between 160°C and 250°C, the bitumen emissions of concern include high concentrations of variable mixtures of inorganic particulate and organic

compounds that include aliphatics, polycyclic aromatic hydrocarbons (PAHs) and heterocyclic aromatic compounds containing sulfur, nitrogen and oxygen.[1]

From the interviews with the asphalt companies, there was consensus that there had been changes to bitumen and their mix in the preceding years but they did not think that fuming had increased. However according to a survey carried out by AWU in 2017, 60% of the asphalt workers who responded (N=152) noticed changes to the mix in regards to fuming in the last 10 years.

"The asphalt smells completely different to when I started 10 years ago. The fuming levels and smoke now makes you sick and is unbearable. I started on a footpath crew and was barrow boy for a long time - the fumes and smell never used to make me sick and I was right in the thick of it." [AWU survey]

"There is a lot more fuming in the last 5 years and smells a lot more. [AWU survey]

"Depends on batch plant or bitumen, some smokier than others." [AWU survey]

2.2 Sources of bitumen

According to the Federal Department of the Environment and Energy's Australian Petroleum Statistics (January 2017), a large proportion of the bitumen used in Australia has been imported from refineries around the world, primarily from South Korea, Singapore and Thailand. Currently, Viva Energy's Geelong refinery is the only manufacturer of bitumen in Australia.

Australian asphalt companies predominantly source their bitumen from suppliers who purchase bitumen offshore from a number of international points. The main organisations in the industry are ExxonMobil Australia, Viva Energy Australia, SAMI and Bitumen Importers Australia (BIA).

2.3 Types of bituminous binder

Asphalt is made by adding the bitumen to heated aggregates and blended with additives at an asphalt plant. This blended bitumen mix is then poured into the back of a truck to go to a work site. Asphalt companies must comply with the state road and traffic authorities' specifications for binders.

Over 90% of bituminous binders used are conventional (unmodified) bitumen. According to AAPA Advisory note 4, it is classified by its viscosity at 60°C and comprises three major grades: Class 170, 320 and 600. The first two are used more commonly. Australian asphalt organisations have the capacity to mix conventional or 'straight-run' bitumen at their plants. Depending on the type of job, such as high wear country roads, different additives are added to the bitumen mix according to state government authority specifications. Information from the asphalt companies with nation-wide operations indicated that every state government had different specifications.

Polymer modified binders are also used if required by these specifications. These are made at a manufacturer's blending plant, where either synthetic polymers or crumb rubber is added, before being transported to an asphalt plant. They are usually ordered and delivered a day or two before their intended use. Due to a push for sustainability and environmentally friendly products, additives such as recycled rubber or crumb rubber are increasingly being used in polymer modified binders.

2.4 Types of asphalt

Asphalt can be supplied in three forms:

- Hot mix asphalt (HMA) – most commonly used (between 95-98%) by the asphalt companies interviewed in this study, largely driven by the regulatory requirements and standards for most road work projects. There are requirements to produce asphalt that meets engineering standards and HMA meets those standards most readily. It is applied at about 170°C to 180°C and has been associated with fuming issues.
- Warm mix asphalt (WMA) – has been in use in Australia but the acceptance of use is still relatively low. It is typically produced at 20-50°C below that of HMA. See Section 4.3 for more information about WMA.
- Cold mix asphalt – less used in comparison to HMA and WMA as it is more suitable for small or temporary repairs to footpaths, access ramps, potholes, storage areas and site works. It is produced using unheated crushed aggregates and bitumen emulsion at 70°C or less.

For HMA, there are no specifications for bitumen laydown temperature as it is grade-specific. Asphalt companies usually get advice from their bitumen suppliers on storage and application temperatures. For example, according to Puma Energy Australia's Safety Data Sheet provided by VicRoads to ISCRR, as a general rule for bitumen Class 170, 240 and 320, bitumen temperature should be kept in the range of 130°C to 200°C and never exceed the industry recommended maximum safe working temperature of 200°C. It also advised that operating temperatures should be kept as low as possible to minimise fume generation.

2.5 Road paving crew's exposure to bitumen fumes

Asphalt companies are contracted to build roads, highways, subdivisions and bridges. Generally, a crew comprises approximately nine people. Paving machines are used for most of the work, with minor sections by hand with a rake and a shovel. There is always an element of hand spreading to ensure asphalt is laid at the right thickness and levels as machines cannot lay effectively in every corner.

From the interviews conducted with asphalt companies, it was understood that crews generally work between 8 and 10 hours a day, which included travelling from depot to site, setting up gear and traffic control, paving a run, cutting old roads out, disposal, cleaning up and other associated tasks. The approximate potential exposure to bitumen fumes during actual asphalt laying was between two to six hours a day. However, exposure was described as not continuous for that length of time.

"…it's not just constant paving either. You might pave a run, then you stop, then you come back and you pave another run."

According to APPA Advisory Note 14, several bitumen suppliers and asphalt companies completed an SBS Bitumen Fume Monitoring Project (no year given) and found that the job that had the highest exposure to bitumen fumes was the paver driver, followed by screed board operator, raker and ganger.

This corresponds with findings in a study carried out by the German Bitumen Forum between 1991 and 2005 (Table 3). The paver operator constantly stayed above the hot asphalt and the screed operator worked closely to the fresh paved asphalt with a continuously new surface. Workers in both of these tasks had higher levels of exposure, depending upon wind direction and weather.

Table 3. Summary of exposure to bitumen vapour and aerosols for different areas of work

Areas of work	Number of measurements	95th percentile in mg/m³
Production of bitumen	17	2.6
Production and transport of asphalt:		
Control centre	8	0.8
External area	6	0.7
Transport of asphalt	14	4.3
Using rolled asphalt in road building:		
Paver operator	115	6.5
Screed operator	141	10.4
Roller driver	42	2.6

Source: The German Bitumen Forum[3]

2.6 Cleaning Agent

Equipment used for work with asphalt, especially with HMA, needs to be cleaned on a daily basis. For decades, diesel or diesel-based solvents have been used as slip agents to soften and strip off the cooled aggregates that are stuck on the equipment. However, diesel may contribute to fume generation.

Two companies reported that they had moved towards using more organic-based and biodegradable products as slip agents while the other two companies stated they were using and trialling a variety of products, including diesel. According to an AWU survey carried out in 2017, 57.9% of the respondents stated diesel was used as a slip agent, whereas 41.5% said they did not use diesel (0.7% unsure).

3. FINDINGS: HEALTH EFFECTS ASSOCIATED WITH BITUMEN FUMES EXPOSURE

Key messages

Acute health effects

- Exposure to bitumen fumes has been associated with acute health effects, such as eye, nose, throat and skin irritation, headaches, nausea and respiratory discomfort.
- Bitumen companies suggested that:
  - Health effects related to fuming loads are 'occasional'
  - Organisations are very responsive to events when they occur
- The sample of paving workers from the AWU survey suggested that:
  - Health effects related to fuming loads have been experienced by a large proportion of workers
  - Organisations are sometimes responsive to events when they occur
- The AWU suggested that under-reporting of events was a significant problem, due to worker characteristics, desire to get the job finished, fear of reprisals and perceived lack of response from management.

Chronic health effects

- The IARC has concluded that occupational exposure to straight-run bitumens and their emissions during road paving are 'possibly carcinogenic to humans' (Group 2B)
- Asphalt companies were not able to provide any evidence indicating risks of chronic illness due to long-term exposure to bitumen, and the Tasmanian bitumen workers report was unable to provide a clear picture on longer term effects from bitumen exposure.
- Data from the AWU survey of workers revealed that 76% of workers were concerned about the long-term effects of exposure to bitumen fuming.

Fume monitoring and testings

- Asphalt companies engage NATA-accredited laboratories to carry out independent testing such as job site monitoring and personal monitoring.
- With current testing demonstrating safe levels and workers reporting adverse health effects, the AWU suggested that testing needs to be reviewed and more investigations required to find out what is causing these adverse health effects.

3.1 Acute health effects of exposure to bitumen fumes

Exposure to bitumen fumes has been associated with acute health effects, such as eye, nose, throat and skin irritation, headaches, nausea and respiratory discomfort (Table 4).

Table 4. Representative findings from the Environmental Scan

Agency (publication year)	Country	Findings
Australian Institute of Occupational Hygienists (AIOH) (2016)	Australia	Hazards and risks associated with long term exposure to PAHs through inhalation/ingestion include cough, chronic bronchitis and haematuria.
Breathe Freely	UK	Hot bitumen work releases fumes containing polyaromatic hydrocarbons (PAHs) as well as particulate matter, which, when inhaled, can cause irritation of the respiratory tract and possibly lung cancer.
Concawe (2003)	Europe	Excessive exposure to these fumes can cause respiratory irritation.
French Agency for food, Environmental and Occupational Health and Safety (ANSES) (2016)	France	Epidemiological studies have shown that worker exposure to bituminous products and their emissions are linked to respiratory effects (asthma, chronic bronchitis, etc.). Cardiovascular and immunotoxic effects are also suspected.
NIOSH	US	Effects include irritation of the eye, nose, throat, skin, and respiratory tissue, fatigue, headaches, dizziness, nausea, stomach discomfort and insomnia.
OSHA	US	Health effects from exposure to asphalt fumes include headache, skin rash, sensitization, fatigue, reduced appetite, throat and eye irritation, cough, and skin cancer.
WHO	International	Irritation of the serous membranes of the conjunctiva (eye irritation) and the mucous membranes of the upper respiratory tract (nasal and throat irritation). Lower respiratory tract symptoms such as coughing, wheezing, shortness of breath, and changes in pulmonary function.
WorkSafeBC	Canada	Asphalt fumes can cause serious and permanent injury, such as cough, fatigue, headache, reduced appetite, cancer, skin rash, throat and eye irritation.

3.1.1 Current perspectives on acute health effects

Workers' perspective

Table 5 shows results from the 2017 AWU survey of 132 road paving workers. They were asked whether they had suffered from any of the conditions listed below (Table 5) after exposure to asphalt fuming. This data suggests that large proportions of the paving workforce have experienced adverse health effects at some time while working. However, it is not clear from this data how often workers suffered from these conditions, whether the problem persisted, whether they reported the incident to the organisation or whether they sought medical attention.

Table 5. Survey results from AWU Victorian paving workers

Condition	No. of respondents (N=132)	% responses
Sore, watery/irritated eyes	89	67%
Irritated skin	50	38%
Difficulty breathing/coughing	78	59%
Nausea	52	39%
Vomiting	11	8%
Headaches	100	76%
Blood nose	29	22%
Other	18	14%

From the survey, 65% of respondents indicated that they had concerns about asphalt or bitumen on-site; and their main concerns related to fuming and smells (46.2%).

AWU highlighted excessive fuming from specific products. In one case, product imported from South Korea in 2013 resulted in many workers getting sick. Similarly, in South Australia, the AWU stated that workers complained of multiple health issues when they worked with material from a new German-designed asphalt plant, which used up to 85% recycled asphalt.

"… five guys down with respiratory issues and two blokes were in hospital with full respiratory shutdown."

"All the guys were getting sick, they were all rotating – all had chest problems, respiratory problems, like they had a chest infection, and I was the only one that didn't because I was wearing my mask all the time."

The 2005 report on Tasmanian Bitumen Workers Issues also found that the immediate effects of exposure to bitumen fumes were irritations of the eyes, nose and throat with associated symptoms of discomfort, redness, watering eyes and coughing. The effects were generally transient and subsided with removal from exposure. Skin irritation with itching and rashes were reported as well as other symptoms including nausea, stomach pains, reduced appetite and headaches following acute exposures to bitumen fumes.

Asphalt companies' perspective

Information from asphalt companies provided a different perspective. Overall, they were relatively consistent in terms of the low frequency of reported health effects.

"I don't have figures in front of me, but probably over the last 10 years, I suppose six to 10 acute effects that have occurred, like that sort of thing."

"Looking back on the history of our fuming incidents in Victoria or issues raised with a mix over the past six, seven years, we've got three issues. [One was related to acute health effects]"

"You might go for six months and then you have nothing, and then all of a sudden you get a few … we do an investigation to what product we're making and what was going on. It's not a consistent comment."

All the bitumen organisations included in the scan acknowledged that some workers had issued complaints concerning irritated eyes, nose or throat, but that these events were rare, and the discomfort was temporary.

"We get acute effects like irritation to the nose and throat and eyes, and that sort of thing, which – remove the person from the job, and then a day later those symptoms pass."

In some cases, adverse health effects have been attributed to the characteristics of workers, including individual susceptibility or intolerance to certain chemicals (like allergic reaction); or lack of safe working behaviour.

"A person 10 years ago – more, actually 15 years ago, that was quite susceptible to an additive that went into a bitumen, and they just couldn't work with that product. It didn't matter – it was like an allergic reaction. You'll find that – not often, but it's possible."

"It's almost like the peanut allergy … I suspect, a little bit the same as fuming. Some people don't have an issue, some people have sore eyes…."

"It's that subtle difference between whether they hang their head over the bin where the asphalt's poured into, or whether they stand back … So sometimes people just do the wrong thing, then end up with that high exposure."

3.1.2 Reporting and response to complaints about fuming loads and health effects

All interviewees from the asphalt companies included in the scan indicated that they were very responsive to any complaints about fuming loads. They all stated that their organisations had formal and informal processes for managing complaints.

Typically, an investigation would first be carried out internally at their facilities, to check whether there were any issues such as the temperature, additives used, and tank storage. Laboratory testing was carried out if necessary. If nothing conclusive was found, the batch of bitumen in question would be traced back to their supplier to determine if a different bitumen was sourced.

For example, as a result of an excessive fuming incident some years ago, an asphalt company now mandates that asphalt temperature must be controlled at 170°C or below. The company also put in place a code of practice and guidelines with their bitumen supplier to ensure that the imported bitumen would not cause fuming issues.

In some cases, organisations attributed the cause of irritations to specific products or sources of product; and consequently, investigated and stopped using those products or sources.

"So even though the results were showing okay, there were side effects out on site… we've got a pretty low tolerance for those kinds of things, so we banned the product since then."

"It was highlighted, and therefore we reacted to that. They did complain about mainly sore throats from this product. Once we did that, we did a number of things – the first one being, let's stop using it. We just ceased using it until we investigated."

"We had one instant when we had compliance shut down - excessive fumes from a mix supplied… When it was raised with our supplier, they've taken it seriously and they've just gone back and investigated it, but that's how we know that in part and different feedstocks can vary."

One of the asphalt companies also reported that they offered medical examinations to employees who were exposed to fuming at a particular site; and that no health problems were identified.

"What we also did was a whole suite of medical investigations for each of the individuals as well. We did that essentially on a volunteer basis... They did get quite a lot of testing through their lungs, through blood, through whatever else the doctors thought was required. Fortunately for everybody there was no health concerns that came out of that, so it was, I guess, a positive."

Interviewees claimed that, despite investigations following complaints, no underlying causes were identified as there was no pattern in the product, processes, conditions or setting that could be recognised.

The AWU suggested that problems with fuming loads were largely unreported; and even when an excessive fuming load was reported, they often decided to "lay it and get out of here". Reluctance to report issues was believed to be due to several reasons (Table 6).

Table 6. Reasons for workers' reluctance to report (from AWU survey)

Reason	Quote
Desire to complete the job	"It's like a tightly-run ship, and you stop and it affects everybody else. So stopping, reporting, sending a load back is a huge issue."
Worker characteristics	"English isn't their first language … don't want to be dogs to the boss, don't want to dog each other on the crew … I'll sort it, I'm tough."
Perceived lack of response	"Because they were sick of it, they were sick of the fumes, and they tried to report it, and they tried to use the near-miss hotline and all the rest of it, and they were getting nowhere."
Lack of trust in testing methods	"'Cause they're saying that the testers, they don't work. They're putting them inside where the asphalt is at its most fuming, didn't – putting them on top of the exhaust stack, and they weren't registering."
Fear of reprisals	"The guys are just too scared. Like, they had redundancies three years ago and they got rid of all the ones that made that noise."

In results from the survey, comments about the employers' responses to problems were sometimes contradictory. For example, a small number of workers suggested that there was a need for more

communication and feedback about workers' concerns; and others indicated that communication was good and there were no problems.

"Management don't get back to us." [AWU survey]

"When we have issues, we speak to office. They take mix back if it's not good; very rarely (sic) happens." [AWU survey]

3.2 Chronic health effects of exposure to bitumen fumes

The risk of cancer due to bitumen exposure has continued to be a key concern since IARC first evaluated the relationship in 1984. In 2011, IARC concluded that occupational exposures to straight-run bitumens and their emissions during road paving are 'possibly carcinogenic to humans' (Group 2B).(1)

A majority of the agencies and authorities around the world that we identified have not classified the carcinogenicity of various forms of bitumen, which may be due to the weak evidence between bitumen exposure and development of cancers. One exception is US NIOSH (Table 7) which included asphalt fumes in their carcinogen list due to skin tumours found in animal studies[1]. Safe Work Australia has not made any classification for bitumen fumes.

Table 7. Health classifications of bitumen by various agencies and authorities

Agency	Substance	Classification
American Conference of Governmental Industrial Hygienists	Asphalt (bitumen) fumes [8052-42-4]	A4 - Not Classifiable as a Human Carcinogen
International Agency for Research on Cancer (2013)	Occupational exposures to hard bitumens and their emissions during mastic- asphalt work	Group 2B – Possibly Carcinogenic to Humans
	Occupational exposures to oxidized bitumens and their emissions during roofing [64742-93-4]	Group 2A – Probably Carcinogenic to Humans
	Occupational exposures to straight-run bitumens and their emissions during road paving [8052-42-4, 64741-56-6	Group 2B – Possibly Carcinogenic to Humans
California Safe Drinking Water and Toxic Enforcement Act	Extracts of steam-refined and air refined bitumen	Listed as carcinogen
European Union Classification (Annex VI of CLP-Regulation (EC) No 1272/2008	Bitumen	Not classified
	Asphalt, Oxidized	Not classified
US National Institute for Occupational Safety and Health	Asphalt Fumes	NIOSH Carcinogen List

[1] https://www.cdc.gov/niosh/npg/npgd0042.html.

Agency	Substance	Classification
US National Toxicology Program	Asphalt Fumes	Evaluation deferred
Concawe (The Oil Companies' European Association for Environment, Health and Safety in Refining and Distribution): Report No. 8/12, 2012	Bitumen Asphalt, Oxidized	Not classified Not classified

Source: Eurobitume[4]

Workers' perspective

The report on Tasmanian bitumen workers issues did not provide a clear picture for long-term effects. It reported that information on individual Tasmanian worker' exposure to bitumen was limited and it was not possible to determine if any individual had any occupational cancer on the basis of the interviews conducted.

The AWU representative suggested that some adverse health effects are chronic.

"About three or four guys in the last six months - that've told me that they've got chronic sinus issues. Two of them have said they haven't been able to taste or smell for the last five or six years." [AWU]

Data from the survey of workers also suggested that 76% of workers were concerned about the potential long-term effects of exposure to bitumen fuming.

"I assume the fumes are not real good for you because it says it on the dockets." [AWU survey]

"Headaches have become almost normal and people have noticed my breathing is very heavy." [AWU survey]

"[the worker in question believed] that the over exposure to asphalt and bitumen played a contributing factor to his son's disability... Aside from his son's issues, he now suffers from chronic sore throat and coughing which he attributes to his over exposure to working in the industry." [AWU survey]

Asphalt companies' perspective

None of the asphalt companies had information that showed risk of any chronic illness to workers over long-term bitumen exposure.

"No, there's not been any sort of risk of chronic illness for the workers that's come back and add to reports."

3.3 Fume monitoring and tests

One of the asphalt organisations interviewed did fume monitoring and found that emissions and fuming were at their acceptable levels when temperature was kept at or below a set temperature.

"What happens at 170 degrees and below, generally, the emissions are quite acceptable and the fuming is quite acceptable. It doesn't visibly fume, and therefore rarely affects people as well. When you go above 170, you get up to 190 degrees, exponentially it increases significantly very quickly."

Asphalt companies also engage NATA-accredited laboratories to carry out independent testing and monitoring studies on bitumen fuming periodically, and sometimes on demand, to check for compounds such as PAHs. Monitoring may occur at a plant, a job site and/or by personal monitoring. So far, results showed that all measures of exposure to bitumen contents and fumes were within accepted limits.

"Everything they test for, I think, generally, it's either below detectable limits or below the exposure limits. It's all the organic compounds and organic gases."

"We've done a lot of testing… The asphalt plant is done frequently on an annual basis. I know we've *done a few of the onsite ones… They've all been well within the limits."*

"And part of that we did testing with the manufacturing process and then crumb [rubber bitumen]. So, six monitors and also personal monitors by the operators as well. No issue there."

In contrast, according to the AWU survey, 132 out of 152 respondents reported experiencing one more conditions or symptoms, after being exposed to bitumen fumes at work (Table 5). AWU perceived this contradiction as a problem and a need for testings to be reviewed. Perhaps more sensitive testings should be undertaken to identify the relevant 'hazards' that are associated with acute health effects. However, it was not specified what the lower thresholds should be or what alternative tests should be undertaken. From a rigorous scientific point of view, one of the asphalt companies suggested that monitoring should be done statistically to cover various types of situations, instead of a snapshot quick study that was usual practice.

"If it's fuming, and the guys are getting sick, and it's coming back clear, they're not testing for what's making them sick… we need to find out what's making these guys sick, for one. I think the testing needs to be reviewed." [AWU]

"Any of the data we have captured, hasn't necessarily given us any concerns. ... But having said that, that doesn't mean that there isn't any, and that we haven't found them."

"The guys were getting itchy skin, sore eyes, some difficulties breathing, so even though the results were showing okay, there were side effects that were out on site."

In relation to crumb rubber asphalt, the National Asset Centre of Excellence (NACOE) conducted emissions monitoring on crumb rubber with conventional polymer modified open graded asphalt. In their 2017 report for the Department of Transport and Main Roads in Queensland, it was found that emissions from crumb rubber mixes and conventional polymer modified mixes were comparable. While the report also found elevated levels of benzene in the crumb rubber mixes compared to polymer modified mixes, it was noted that the study was carried out in an emissions chamber and this might not represent actual exposure of workers to harmful emissions on site.

Responses from the AWU survey showed that 51% of the 151 respondents worked with crumb rubber asphalt (at or around the time of the survey), 42% replied no and 7% were not sure. From the interviews conducted, it was noted that careful deliberation was needed in following the overseas' trend in using crumb rubber asphalt, as the composition of tyres (such as aromatic oils) in Australia and other countries might differ.

"So, it could be that it's fine to do it over there, because it's different composition of crumb rubber. If we want to incorporate this, we need to do the testing here on our properties."

Biological Monitoring

One of the asphalt companies interviewed is redeveloping a more comprehensive biological monitoring system for their road paving crew. While biological testing has been undertaken occasionally for certain workers who are using a particular hazardous chemical, this is a new program for the organisation's road paving crews.

They plan to carry out full exposure assessments on each of the different bitumen products they use. Biological monitoring such as urine testing for bitumen metabolites will be carried out to find out whether the road paving crew's ingested dose following bitumen exposure correlates with environmental measurements. The strategy is to undertake a rigorous study in each state, to collect data from various similar exposure groups (SEG) so that they could look at the statistical distribution of that data in order to arrive at a meaningful interpretation.

4. FINDINGS: RISK MANAGEMENT

Key messages

- Occupational exposure limits for bitumen emissions vary in numerical values and methods of evaluation around the world.
  - According to Safe Work Australia's *Workplace Exposure Standards for Airborne Contaminants*, the exposure standard for bitumen fumes (CAS# 8052-42-4) at 8-hour time-weighted average is set at 5 mg/m³.
- All asphalt companies reported that they had preventive measures in place to mitigate excessive fuming and responsive measures in the event it happens:
  - Engineering controls, operational checks, reporting channels, employee medical checks, safety culture and personal protective equipment (PPE).
- The AWU emphasized the need for better reporting from road paving crews about their concerns.
  - AWU launched an "Asphalt Reporting App and Hotline" in October 2018.
- Warm mix asphalt (WMA) could be considered as a replacement for traditional hot mix asphalt (HMA) in some circumstances:
  - WMA require lower production and laydown temperatures, typically by 20–50°C, compared with conventional HMA.
  - One of the advantages of WMA is less fumes.
  - The asphalt companies interviewed are technologically-ready to supply WMA, but WMA is yet to be adopted more widely in Australia due to current specifications by state governments.

4.1 Occupational exposure limits

There are several occupational exposure limits and voluntary guidelines for bitumen emissions around the world. They vary in respect to numerical values and methods of evaluation. For example, the German and Australian threshold limit covers the sum of fumes and aerosols, whereas the US limit only relates to the aerosol fraction. In some countries such as the US and France, the occupational exposure limits are not legally binding.

Table 8 shows the Threshold Limit Values (TLV) of selected countries, using Time-weighted average (TWA). TWA means the maximum average airborne concentration of a substance when calculated over an eight-hour working day, for a five-day working week.

Australia's Work Health and Safety (WHS) Act requires risks to health and safety be eliminated so far as is reasonably practicable. If it is not reasonably practicable to eliminate risk, it must be minimised. According to Safe Work Australia's *Workplace Exposure Standards for Airborne Contaminants* in effect on 18 April 2013, the exposure standard for bitumen fumes (CAS# 8052-42-4) at an 8-hour time-weighted average is set at 5 mg/m³.

The German Bitumen Forum found that exposures were the highest at 10.4 mg/m³ in road paving with a maximum laying temperature of approximately 180°C. Apart from rolled (road) asphalt, the

German Bitumen Forum's work also included the production of asphalt and mastic asphalt. Therefore, taking all the results from these measurements, the Hazardous Substances Committee in May 2000 passed a threshold limit in air for fumes and aerosols from bitumen at 10 mg/m³. However, a new German Ordinance on hazardous substances was introduced in January 2005, resulting in technically-based threshold limit values, as opposed to health-based ones, as no longer valid. Consequently, there is currently no limit value for vapours and aerosols of bitumen in Germany.

In the US, there is no specific OSHA standard or permissible exposure level of asphalt fumes, although a 5 mg/m³ permissible exposure limit (benzene soluble) was proposed in 1992. Other regulatory agencies in the country have released their own occupational exposure level recommendations. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a TLV of 0.5 mg/m³ as an 8-hour time weighted average while NIOSH recommends no more than 5 mg/m³ for a maximum exposure per 15-minute short-term exposure in addition to assigning a carcinogenicity designation.

According to a letter of interpretation released by OSHA in January 2019, as a result of the industry's ongoing engineering control efforts, the asphalt fumes (benzene soluble) TLV is typically only approached under extremely limited circumstances, such as paving in tunnels with specialized asphalts.

There is a need for a standardized method for measuring bitumen emissions, as several methods are used in different countries. As Safe Work Australia points out, exposure standards merely establish a statutory maximum upper limit and do not necessarily draw a dividing line between a healthy or unhealthy working environment due to individual susceptibilities.

Table 8. Threshold limit values in different countries by time weighted average (TWA)

Country	Substance	Limit (mg/m³)
Australia	Bitumen fumes	5.0
Belgium	Asfalt (Petroleum) (Rook), Pétroles (Bitumes de) (Fumées)	5.0
Canada	Benzene soluble part of aerosols of bitumen	0.5
Denmark	Bitumenrog	1.0
Finland	Organic dust (also for bitumen vapours)	5.0
France	Bitumen emissions	5.0
Germany*	Bitumen	10.0
UK	Benzene soluble (PAHs)	5.0
New Zealand	Asphalt (Bitumen) Fumes	5.0
Norway	Asfalt (royk)	5.0
Spain	Asfalto (petróleo) humos	5.0
The Netherlands	Asphaltrook (bitumineus)	5.0
US	Benzene soluble part of aerosols of bitumen	0.5

Sources: The German Bitumen Forum, NIOSH, SafeWork Australia, SafeWork NZ, Breathe Freely UK.

* invalidated by new regulation in 2005

4.2 Risk mitigation measures

There are numerous guidance materials and codes of practice established by international agencies, industry peak bodies and bitumen suppliers for asphalt companies on managing risks when handling or manufacturing bitumen. In terms of worker exposure to bitumen fumes, cautionary statements are often included, albeit with limited information. Workers are generally advised to control bitumen temperature to minimise fuming and wear appropriate respiratory protection equipment when working in poorly ventilated spaces.

Engineering controls can also be fitted to reduce bitumen fuming. In the US, most highway pavers, especially those manufactured since 1997, are required to have an exhaust ventilation system installed on them in accordance with NIOSH standards. However, smaller pavers are not required to comply.

The French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS) did an evaluation of bitumen fume capture efficiency on asphalt road pavers between 2009 and 2011. Not only did fume extraction systems reduce exposure by 55%[2], they also improved working conditions by protecting workers from the heat[3]. Recommendations were adopted and a national exposure measurement campaign in 2014-2015 showed approximately one-third reduction in operator exposure on sites where the paver was equipped with an extraction system.[3]

In Australia, AAPA's recommendations concerning asphalt and asphalt fumes in its *An Introduction to Health and Safety in the Flexible Pavement Industry*, are[(5)]:

- Asphalt mix: avoid excessive temperatures of the asphalt during production and application
- Slip agents: seek alternatives to diesel for release agents
- Exhaust gases: adapt the layout of machinery and maintenance of diesel engines in order to minimise the exposure to exhaust gases
- Ventilation: create ventilation in those places with relatively high exposure levels
- Organic solvents: avoid the application of organic solvents used in the temporary softening of bitumen at the asphalt mixing plant

4.2.1 Findings from interviews with asphalt companies

Interviewees were asked to comment on their organisations' OHS policy in relation to protection for workers from exposure to bitumen contents and fumes during road construction and repairs. All asphalt companies reported that they had implemented preventive measures against excessive fuming and responsive measures in the event it happened. Their responses varied in scope and depth.

Table 9 is a summary of their responses, which are categorized into engineering controls, operational checks, reporting channels, employee medical checks, safety procedures and personal protective equipment (PPE). The table outlines information provided during the interview and may not reflect all bitumen risk mitigation measures of the organisations.

[2] https://www.colas.com/en/responsible-commitment/other-challenges/chemical-risk
[3] http://en.inrs.fr/our-activities/key-projects/bitumen-project.html

Table 9. Summary of asphalt companies' responses on bitumen fumes risk mitigation measures

Organisation	Response on bitumen fumes risk mitigation measures
Engineering controls	Asphalt production and loading temperature is mandated at or below a set temperature (e.g. 170°C). Fume extraction systems are installed on pavers and load-outs at the plants.
Operational checks	Every load of asphalt that goes out from the site is tested for temperature. If load is deemed too hot, either cool it down or dump it. Crews have the power to stop a job where they feel it is unsafe to continue. QA documentation, e.g. generally checking most loads before they get tipped into the paving machine. When lab testers take samples for various compliance and performance testing, they take load temperatures as well.
Reporting channels	Crews can make a direct phone call to either their supervisor or their manager, or if they prefer, they could make use of anonymous 24-hour hotline or open 'near-miss' lines to report issues or concerns. If no Health & Safety representatives (HSRs) present, crews have access to the health and safety committees and an OHS representative. A paper booklet, where crews can raise an incident in a little sort of pocket pad and forward it.
Employee medical checks	Pre-employment medical checks and health surveillance such as audiometric tests every two years and spirometry tests every four to five years. If the doctor perceives further investigations required, crews may go for X-rays.
Safety procedures and PPE	PPE such as heat resistant boots, gloves, hearing protection, etc are provided, but in terms of fuming, no special PPE is required. If crumb rubber asphalt is used, there are strict procedures and high protections for the crew such as lots of job rotation and the correct PPE (e.g. canister breathing apparatus) must be worn. Whenever there is a product change, employees are informed via a 'toolbox' and Material Safety Data Sheet (MSDS) so that they may be aware what might be in that product that is different. During employee induction or re-induction, they are given a small card that reminds them that they have a right to stop for safety at any time.

4.2.2 Findings from interview with the Australian Workers Union (AWU)

In the health and safety interests of the road paving crew, the AWU representative felt that there is a need for:

"Reporting, reporting, reporting"

It was suggested that incidents are unreported or under-reported for reasons discussed in Section 3.1.2. In response to this, AWU launched an "Asphalt Reporting App and Hotline" in October 2018 to encourage road paving crews to speak out and record their concerns, if any.

More support for Health & Safety Representatives (HSRs)

There is limited HSR membership at asphalt plants. Only one asphalt company from the interviews indicated they have an HSR in every road paving crew. The AWU felt that there should be one in

every single crew or a quality assurance and control officer to identify fuming loads. Even though asphalt companies have set temperature controls for loads, 51% of the 151 respondents to the AWU survey said they had concerns with the asphalt temperature not matching the temperature written on the docket.

Prudent use of slip agents

Asphalt companies and road paving crews were encouraged to use slip agents other than diesel and avoid using diesel between loads. Also, slip agents should not be overused when polymer modified binders such as crumb rubber are used, as they tend to be gluggier in consistency.

Readily available product-specific material safety data sheet (MSDS)

Product-specific MSDS, not just generic MSDS, should be accessible or easily obtained by road paving crews.

"I struggled to get one [MSDS], on the ground, I didn't get one at all. We requested it, I've got my own emails from when I was HSR back on the ground, and they could never produce one. Or they did, it was a generic one for the bitumen, but none of the other products in there. None of the rejuvenator oils or the waxes or the recycled products." [AWU]

4.3 Warm mix asphalt as an alternative

Warm mix asphalt (WMA) has increasingly been used as a replacement for traditional HMA in many countries. The concept originated in Europe in the early 1990s and, since then, several WMA technologies have been introduced into Australia. It is widely known that WMA requires lower production and laydown temperatures, typically by 20-50°C, compared with conventional HMA.[6-8]

In Austroads' and Australian Road Research Board (ARRB) Group's *Laboratory Evaluation for Warm Mix Asphalt*, one of the advantages associated with a reduction in asphalt production and compaction temperatures is improved conditions for operators due to less fumes.[8] Findings from the German Bitumen Forum concur, citing the following benefits of WMA:

- Lower energy consumption
- Reduced carbon dioxide production
- Lower equipment wear, thus longer life
- Lower emissions at the mixing plant
- Minimal ageing of binders during production and laying
- Fewer vapours and aerosols

The asphalt companies interviewed have expressed readiness and eagerness for WMA to be used more widely in the country. They have made capital investment in WMA technologies by upgrading and equipping their facilities with foam units. In accordance with industry specification, they are able to register their facility as both hot or warm mix.

However, asphalt companies cited insufficient awareness among clients, current specifications by state governments and hesitation to adopt new product offerings have led to limited use of WMA in Australia. Asphalt companies are required to ensure their products comply with engineering standards set by state governments and local councils and these standards are currently met more readily by HMA.

"While warm mix asphalt is not prohibited in the specification, it is also not mandated either. It probably comes more from an individual company drive for both environmental safety and operating cost efficiencies."

"We'd love to use them more often … that would be the ultimate … but customers and clients and others who hold the specifications aren't as keen, unfortunately."

"One is it's going to save us money on heating the aggregate, and then producing asphalt at a lower temperature, so it's a benefit to the business, but also it is going to reduce fuming even more. So, there's nothing, to my knowledge, that's stopping us doing it, and doing it more. It's really just an acceptance of both industry and government."

According to figures released by the US National Asphalt Pavement Association (NAPA), nearly 39% of asphalt pavement mixture produced in 2017 was WMA. The use of WMA in the US had tracked at about a third of all asphalt mixture production since 2013. While no Australian official figure was found in the desktop scan, one of the asphalt companies believed that Australia has significantly less WMA-made roads (possibly as low as 1-2%). While the shift to using WMA will take time, there is an argument that for wider and more successful adoption of this technology in Australia, a thorough understanding of other countries' experiences should be done in tandem with a review of the performance of WMA under Australian conditions[8].

5. INSIGHTS AND IMPLICATIONS

Clarification of the possible short- and long-term health effects of bitumen fumes is urgently needed. It is clear from the grey literature, two separate surveys of road paving workers, and discussions with asphalt producers that there are some short-term health effects including eye, nose, throat and skin irritation, headaches, nausea and respiratory discomfort. However, it is not clear how often workers experience these conditions and whether the problems persist.

The asphalt companies reported that the acute health effects related to fuming loads are random and not common, in contrast to the views of the AWU and road paving workers surveyed by the AWU. Acknowledging the safety measures and testing practices currently employed, there may be under-reporting by workers as a result of a desire to get the job finished, differences in worker characteristics, perceived lack of response from management, lack of trust in testing methods and fear of reprisals.

Reports of long-term health effects of bitumen included sinus problems and loss of smell and taste, and 76% of road paving workers in the AWU survey indicated they were concerned for their long-term health. A causal relationship between bitumen exposure and development of cancers has not been shown, and in 2011, the IARC concluded that occupational exposures to straight-run bitumens and their emissions during road paving are 'possibly carcinogenic to humans' (Group 2B).

It would be prudent to promote good occupational hygiene practices, such as reducing emissions, developing more sensitive testing for hazardous substances and promoting use of protective clothing and equipment to minimise exposure to bitumen fumes. Continuous improvement in engineering controls such as the fume extraction systems and modern safe work practices have played a significant role in keeping exposures as low as reasonably possible. If the reporting culture can be improved across the board, more data will be captured to inform further improvements, and the industry as a whole will gain a greater understanding of the issues related to bitumen.

There are several points for consideration for the asphalt industry in Victoria, and to a certain extent in Australia:

- More HSRs to be appointed and trained in road paving crews.
- Review the criteria for testing so that the right hazardous substances are tested and the sensitivity of testing is appropriate.
- A more standardized form of fume monitoring; and routine use of biological monitoring to assess the impact on individual workers.
- More investigation in the use of crumb rubber asphalt in the Australian context.
- Explore the possibilities of using WMA more widely in Victoria and Australia. Use of regulatory methods to support use of WMA as the first option, where the circumstances are appropriate, may encourage more widespread use.

  Recommendations from the German Bitumen Forum is to use WMA wherever possible and always use WMA in tunnels. While detailed findings are beyond the scope of the Environmental Scan, long-term performance, economic and environmental impact of WMA have been investigated[9-11] overseas in recent years and the applicability of these findings in Australia may be considered.
- More consultation and sharing of information among stakeholders, especially with the road paving crew.

  Apart from the AWU, manufacturers, businesses and other relevant key stakeholders, the workers laying asphalt should be included for consultation.

"If every company was doing something a little bit more formalised, I think if everyone was doing that, and started to share that information, then I think clearly, combined with the research that you're doing, it would be really positive."

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