THE AUSTRALIAN WORK EXPOSURES STUDY (AWES):

POLYCYCLIC AROMATIC HYDROCARBONS

November 2014

The views in this report should not be taken to represent the views of Safe Work Australia unless otherwise expressly stated.

SAFE WORK AUSTRALIA

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PREFACE

The Australian Work Health and Safety Strategy 2012-2022 (the Strategy) describes work-related cancer as a priority disorder and understanding current hazardous exposures and the effectiveness of controls as a research priority. The Australian Work Exposures Study (AWES) was a national survey that investigated work-related exposures among Australian workers to 38 agents classified by the International Agency for Research on Cancer (IARC) as known or suspected carcinogens.

Some polycyclic aromatic hydrocarbons (PAHs) are classified as a known or suspected human carcinogens by the IARC and the work described in this report uses AWES data to:

- estimate the prevalence of work-related exposure to polycyclic aromatic hydrocarbons during relatively common workplace activities
- identify the main circumstances of those exposures, and
- identify the use of workplace control measures designed to decrease those exposures.

This report describes those exposures that occur when typical work activities are carried out by Australian workers—it does not specifically focus on industries suspected of high exposures to polycyclic aromatic hydrocarbons.

CONTENTS

KEY MESSAGES

- Approximately 297 (5.9%) of workers who participated in the Australian Work Exposures Study (AWES) were probably exposed to polycyclic aromatic hydrocarbons (PAHs) when performing common tasks like burning waste, repairing equipment powered by combustion engines like mowers or similar equipment, cooking, fighting fires, and fire overhaul and clean-up.
- The health risks posed by some exposures to PAHs should be well understood, particularly by those undertaking work which is highlighted in work health and safety guides for health surveillance or in guides for specific work activities like foundry work. General information on methods for preventing inhalation and skin contact with chemicals is also provided in the Model Code of Practice - Managing Risks of Hazardous Chemicals in the Workplace.
- Information on the use of controls was not collected for many of the common tasks highlighted above. Information was available for fire fighting, back burning and welding and only about 40% AWES respondents performing these tasks appeared to be using appropriate respiratory protection.
- As a result, about two thirds of exposed workers were assessed as having high or medium task-based exposures to PAHs. While most of these workers will not develop cancer as a result of work-related exposures to PAHs, they are at greater risk.
- Awareness-raising and education efforts are required to increase the use of well-known and readily available controls to prevent exposures when burning wastes, cleaning ash from fire sites or furnaces, fighting fires or back burning and repairing equipment powered by combustion engines.

EXECUTIVE SUMMARY

Background

Cancer is a priority disorder under the Australian Work Health and Safety Strategy 2012-2022 (the Strategy). Better understanding of current hazardous exposures and the effectiveness of controls is a research priority under the Strategy. There are more than a hundred polycyclic aromatic hydrocarbon compounds (PAHs) and they typically exist as complex mixtures. Some PAHs are known or probable human carcinogens (classified as International Agency for Research on Cancer (IARC) Group 1 and 2A carcinogens) but there is no nationally representative or comprehensive information about the nature of this exposure in Australian workers.

The Australian Work Exposures Study (AWES) is a recently-conducted nationwide survey which investigated the current prevalence of work-related exposure to 38 known or suspected carcinogens, including PAHs, among Australian workers. The AWES data provide an opportunity to better understand the extent and circumstance of exposure of the Australian workforce to PAHs.

The aim of the work described in this report was to use AWES data to estimate the prevalence of work-related exposure to PAHs during relatively common workplace activities, to identify the main circumstances of exposures, and to identify the use of workplace control measures designed to decrease those exposures. This report is concerned with those exposures that occur when typical work activities are carried out by Australian workers—it does not specifically focus on industries suspected of high exposures to PAHs.

Approach

The information presented in this report comes primarily from analyses of data from the AWES project. The AWES project involved computer-assisted interviews of approximately 5,000 Australian workers. OccIDEAS — an automated process of expert assessment — was used to assess the likelihood of exposures and estimate exposure levels to 38 known or suspected carcinogens based on self-reported information on work tasks and the controls being used by workers. The likelihood of exposure was assessed as none, possible or probable. Data on tasks that could result in PAHs exposure were extracted and examined for this report.

Prevalence estimates based on the proportion of workers in the AWES sample probably exposed to PAHs were applied to the Australian Bureau of Statistics 2011 Census data to provide prevalence estimates for the Australian working population. The AWES information was supplemented with limited Australian data from other sources, including from the 2008 National Hazard Exposure Worker Surveillance (NHEWS) Survey and the published literature. National level estimates were compared to prevalence estimates found in major overseas studies.

Key findings

Of the workers who completed the AWES survey:

- 297 (5.9%) had probable exposure to PAHs
- 81% of the workers with probable exposure were male
- one third of the exposed persons worked as managers (mainly farmers), and
- 40% of those with probable exposure worked in the agriculture industry.

The main tasks associated with probable exposures were, in decreasing order, burning waste, repairing motors or other similar equipment, cleaning out ash from fire sites, health workers exposed to diathermy smoke (smoke arising from cauterisation during surgery), cooking, and fighting fires and fire overhaul and clean-up.

The main control measures workers reported using were designed to decrease the chance of exposure to PAHs by inhalation, for example wearing respiratory protective equipment (RPE). Information on RPE was not available for all exposed respondents. Among exposed respondents for whom information was available, about 40% appeared to be using appropriate RPE while working.

Exposure levels were assessed as being high or medium in about two thirds of cases based on information provided by workers on work tasks and the controls being used.

If AWES estimates are applied to the Australian working population, approximately 6.7% of all workers could be considered to be probably exposed to PAHs at work. This estimate is significantly higher than that found in overseas studies, with the differences probably reflecting differences in study methodologies in terms of the type of data collected and the approach used to estimate exposure and the different industry proportions in the countries in which the studies were based.

Limitations

The AWES is a national population-based study providing representative exposure information on relatively common activities. Information will be lacking on most industry sub-sectors, specific occupations and specific tasks which are less common or which are undertaken by a relatively small number of people. This is why some tasks that could be viewed as having a high prevalence of exposures to PAHs might have not been represented in the study sample of 5023 workers.

Subjects included in the AWES sample were asked a series of questions about their job and the tasks involved. Some information was also obtained on the use of control measures. However, the information that could be collected on controls was somewhat limited. This was because questions asked in AWES primarily assessed if exposure could occur and then, if possible, the level of exposure; and due to the limitations on the number of questions that could be asked while still encouraging people to participate in the project

Exposure assessments were qualitative and refer to task or activity based exposure levels rather than to exposure standards.

Policy implications

Approximately 6.7% of Australian workers are estimated to be exposed to PAHs when performing relatively common tasks at work. More information is required to understand the level of risk arising from these exposures in terms of cancer outcomes. Some of the health risks posed by exposures to PAHs, the tasks that might result in such exposures and the methods of preventing exposure should be well understood by employers and workers. However, circumstances such as exposure to smoke and ash in many circumstances and exposures during maintenance of motors might not be properly appreciated.

The use of controls by workers in the AWES sample appears to have considerable scope for improvement. Where information on the use of controls was collected, less than half of respondents reported using what appeared to be adequate RPE and many reported not using any controls to prevent exposures. There is an opportunity to prevent work-related exposures to PAHs, and thereby reduce the potential for work-related cancer cases, through efforts to increase the number of workplaces that consistently use high order controls and good work practices to eliminate or reduce these exposures. In particular, efforts could be focused on lowering exposures in those activities where a significant number of workers were assessed as having high or medium exposures and ensuring that exposed workers are supplied with and use appropriate RPE. Examples of these circumstances include workers involved in:

- burning waste
- cleaning ash from fire sites
- fighting fires or undertaking fire overhaul and clean up
- preparing and using ammonium nitrate fuel oil, and
- road building with hot asphalt road mix.

Initial efforts could focus on initiatives that raise awareness or educate persons conducting a business or undertaking (PCBUs) and workers about minimising exposure to PAHs and using well-known and readily available controls to decrease exposures to PAHs.

The inconsistency in classification of benzo[a]pyrene and some other individual PAHs by IARC and the National Toxicology Program compared to the Hazardous Substances Information System (HSIS) listing suggests it is warranted to consider a revision of the HSIS listing of some PAHs to Category 1 and of some others to Category 2.

Further research

Exposures and health outcomes

The AWES project provides qualitative information on current exposures to PAHs based on job tasks. Quantitative measures of PAH exposure in the workplace may be of use to validate the data collected in AWES and to improve understanding of the absolute levels of exposure to PAHs. There was no scope to do this as part of the AWES but this information would be useful for the tasks where workers may be exposed to smoke and ash or when carrying out maintenance on motors.

The use of control measures

The work presented in this report could be complemented by the collection of more widespread and more detailed information on the use of control measures in those work situations highlighted in this report where probable exposures to PAHs were identified, especially where they were assessed as being high or medium. Further research could also help understand why appropriate control measures are not used. Such research could examine:

- the extent to which PCBUs and workers understand the hazards and associated potential risks
- the extent to which PCBUs and workers understand the need for various control measures and how they operate
- the extent to which higher order controls are used
- the adequacy of current regulations and guidance for preventing exposures, and
- the efficacy of current methods for providing risk management information and assistance to PCBUs.

BACKGROUND

Introduction

Cancer is a priority disorder under the Australian Work Health and Safety Strategy 2012-2022 (the Strategy) (Safe Work Australia 2012c). Better understanding of current hazardous exposures and the effectiveness of controls is a research priority under the Strategy. Polycyclic aromatic hydrocarbons (PAHs) are a group of chemical compounds with related structures (two aromatic rings and consisting of carbon and hydrogen) and which are formed during the incomplete combustion of organic material. There are more than a hundred polycyclic aromatic hydrocarbon compounds (PAHs) and they typically exist as a complex mixture. Of those PAHs classified by the International Agency for Research on Cancer (IARC)[1] , some have been classified as Group 1 carcinogens (known human carcinogen), some as Group 2A (probably human carcinogen), some as Group 2B (possible human carcinogen) and many as Group 3 (not classifiable due to insufficient information) (International Agency for Research on Cancer 2010; Straif et al. 2005). There is no nationally representative or comprehensive information about the nature of these exposures. Information on the nature of exposure to hazardous substances such as PAHs would help inform current workplace chemicals policy development activities.

The early efforts of Australian researchers to estimate the number of workers who might be exposed to known or suspected carcinogens such as PAHs relied on applying overseas estimates to Australian labour force data (Australian Bureau of Statistics 2002; Fritschi & Driscoll 2006; Mathers et al. 1999; Morrell et al. 1998; Winder & Lewis 1991). The 2008 National Hazard Exposure Worker Surveillance (NHEWS) Survey attempted to collect information on chemicals used by workers and the controls provided by persons conducting a business or undertaking (PCBUs) to help address this information gap (de Crespigny 2010; MacFarlane et al. 2012). However, the data collected through the NHEWS Survey have limited utility in determining the extent of exposures to specific chemicals or the manner in which workers use controls to prevent exposures. This is because it relied on workers being aware of the specific chemical hazards with which they worked, it provided a low level of detail on controls measures, and the sampling approach meant the results were not representative of the Australian workforce.

The recent work on the Australian Workplace Exposure Study (AWES) (Carey et al. 2014) provided the opportunity to obtain information on the prevalence of exposure to PAHs during typical work activities at a national level. The main part of this report presents an analysis of relevant AWES data. This is followed by a consideration of the implications of the results for policy activity and future work health and safety research.

1. The IARC classification is described briefly in Appendix 1

The carcinogenicity of PAHs

The most authoritative information on the possible carcinogenic effects of PAHs is provided by IARC. While carcinogenic classifications for PAHs range from Category 1 to Category 3, common exposures and exposure circumstances are classified as Group 1 or Group 2A by IARC. The basis of this classification is described in IARC Monograph 92 (International Agency for Research on Cancer 2010) and in an associated journal article (Straif et al. 2005). In terms of tasks associated with exposure to PAHs, IARC identified occupational exposures during coal gasification, coke production, coal-tar distillation, work as a chimney sweep, road paving and roofing with coal-tar pitch, aluminium production as being carcinogenic to humans (IARC Group 1). Exposure during carbon electrode manufacture and exposure to creosote are considered by IARC to probably be carcinogenic to humans (IARC Group 2A). Benzo(a)pyrene is a PAH compound commonly used as marker of overall exposure to PAHs and is classified as Group 1 agent by IARC. Several other agents are classified as Group 2A and many as Group 2B (see Appendix 2). The carcinogenicity of PAHs is based on strong evidence that some PAH types cause cancer of the lung and skin, with limited evidence of a link also with bladder cancer. These assessments are based on evidence in humans, evidence in animals and on mechanistic data (Cogliano et al. 2008; International Agency for Research on Cancer 2010; Straif et al. 2005).

Other organisations have classified PAHs similarly to IARC. The US National Toxicology Program identifies 15 separate agents as “reasonably anticipated to be a human carcinogen” (see Appendix 2) (National Toxicology Program 2011).

Under Australian work health and safety regulations manufacturers or importers must determine if a chemical is a hazardous chemical. At the current time, two classification schemes may be used for this purpose—the Approved Criteria for Classifying Hazardous Substances [NOHSC:1008(2004)] (the Approved Criteria) (National Occupational Health and Safety Commission 2004) or the Globally Harmonised System of Classification and Labelling of Chemicals 3rd Revised Edition (the GHS) (United Nations 2009). The Hazardous Substances Information System (HSIS) (Safe Work Australia 2012b) lists substances that have been classified by an authoritative source such as the European Commission or National Industrial Chemicals Notification and Assessment Scheme (NICNAS) in accordance with the Approved Criteria and provides classification details. Some PAHs are listed in HSIS as Category 2 Carcinogens.

The main non-carcinogenic health effects of PAHs are due to photosensitivity. As the focus of this report is PAHs as carcinogens, the non-carcinogenic effects of PAHs are not considered further.

Information on exposure and control measures

Information from published literature

Low level exposure to PAHs is very common through environmental and dietary sources (Agency for Toxic Substances and Diseases Registry 1995; CAREX Canada 2014; International Agency for Research on Cancer 2010; Straif et al. 2005). Occupational exposure can occur in a wide variety of exposure circumstances. Those identified by IARC are “occupational exposures during coal gasification, coke production, coal-tar distillation, paving and roofing, aluminium production, and chimney sweeping” (identified as Group 1 exposures); and “creosotes” and “occupational exposure during carbon-electrode manufacturing (in aluminium smelting)” (both classified as Group 2A) (International Agency for Research on Cancer 2010; Straif et al. 2005). Most of these exposure circumstances have been or could be suspected to be relevant to Australian workplaces.

The CAREX database provides information on prevalence of exposure to a range of probable and definite carcinogens as classified by IARC. It contains estimates of the numbers of workers exposed to carcinogens at work by industry in 15 countries of the European Union (EU) (exposure data from 1990-93) and four of the 10 countries that joined the EU in 2004 (exposure data from 1997). It also contains summarised exposure data, definitions of carcinogenic exposure, descriptions of the estimation procedures and bibliographic references. The work was undertaken in two phases. Initially estimates were derived from national workforce data and exposure prevalence estimates from two reference countries (the United States (US) and Finland) which had the most comprehensive data available on carcinogen exposures. The most valid value of prevalence (usually the mean of the US and Finnish values) was used as the default value. There was also some modification of estimates based on data in some individual European countries. The overall CAREX data were produced to reflect exposures in the early 1990s in Europe. Information is only available for males and females combined. The prevalence of work-related exposure to PAHs overall in CAREX was 0.7%, with the highest prevalence in electricity, gas and water (3.1%), manufacturing (1.6%), construction (1.3%) and mining (1.0%) (Finnish Institute of Occupational Health 1998; Kauppinen et al. 2000).

It is likely that improvements in work practices and approaches to exposure control and changes in industry distribution over the last two decades would have resulted in a decrease in exposure prevalence levels and/or absolute exposure levels in Australia (and elsewhere) compared to the estimates at the time the CAREX database was developed.

A more recent carcinogen exposure database, CAREX Canada, provides more up to date data and it estimates the overall occupational exposure prevalence for PAHs to be about 2%. The CAREX Canada database identifies the main occupational exposures (in terms of number of people exposed) as being chefs and kitchen workers, mechanics and fire fighters. Industries with the highest prevalence of exposure were restaurants and other cooking establishments, petrol stations and public administration (CAREX Canada 2014).

A recent major study of the work-related burden of cancer in Great Britain included consideration of lung cancer, bladder cancer and non-melanoma skin cancer in relation to PAH exposure. The study employed a detailed methodology for estimating exposure, focusing on data from Great Britain. High exposure was estimated for workers in iron and steel basic industries (51% of workers deemed exposed), manufacture of other non-metallic mineral products (21%), non-ferrous metal basic industries (17%) and manufacture of industrial chemicals (10%). The overall prevalence of exposure to PAHs was based on the CAREX estimates (Rushton et al. 2012; Van Tongeren et al. 2012).

Information on Australian workplaces

There is little published information that addresses the number of Australian workers exposed to PAHs. There are reports examining aspects of exposure in specific circumstances such as aluminium smelting (Di Corleto 2010), fire fighting (Reisen & Tiganis 2007; Reisen & Brown 2009) and a brief mention in a study focussing on environmental exposures (Berko 1999).

Information from NHEWS

The NHEWS study (Australian Safety and Compensation Council 2008; 2009) was a study of Australian workers designed to examine the frequency of exposure to a range of hazards, including workplace chemicals. The study initially focused on key industries (agriculture, forestry and fishing; manufacturing; construction; transport, postal and warehousing; and health and community services) but included all industries in the second phase of data collection. Some information on provision of exposure controls was also collected.

The survey was conducted in 2008 via telephone. All information on exposure to specific hazards and on controls was from self-report. The nature of the data collection meant that the data could not be considered representative of the whole Australian working population or even necessarily quantitatively representative of the specific industries included. However, it provided useful qualitative information and some quantitative information.

Potentially relevant reports published from NHEWS examined exposures to chemicals through skin contact (MacFarlane et al. 2012) and airborne exposures (de Crespigny 2010). However, neither report has useable information specifically on exposures to PAHs. Examination of the unit record data for this study identified 49 subjects who appeared likely to have been exposed to PAHs. The exposure circumstances were:

- exposure to asphalt in road construction (7)
- exposure to smoke from frying (7)
- exposure to smoke from fighting fires or being nearby when fires were burning (7)
- exposure to smoke from sources of smoke such as ovens, incinerators and furnaces (13), and
- exposure to welding smoke (13).

The remaining two persons were exposed in other circumstances. The nature of the information in NHEWS meant there was some uncertainty about whether the circumstances would have resulted in exposure to PAHs but in most instances exposure appeared likely. The 49 subjects represented about one per cent of the NHEWS subjects. It is likely that many probable exposures would not have been identified from the available information but the information indicates in a qualitative sense that exposure to PAHs is not uncommon in the Australian workforce.

Australian workplace chemical regulations and guides

In Australia work health and safety requirements for working with hazardous workplace chemicals are set out in Part 7.1 of the model Work Health and Safety Regulations 2011 (model WHS Regulations) (Safe Work Australia 2011a)[2]. These include requirements for airborne contaminants and PCBUs must ensure the workers are not exposed to formaldehyde at concentrations higher than the relevant exposure standard. PCBUs would be expected to follow the hierarchy of control when controlling exposures to PAHs. PAHs are designated by Safe Work Australia as hazardous chemicals requiring health monitoring (Safe Work Australia 2013a). Information is available for PCBUs on how and when such monitoring is to be undertaken for PAHs (Safe Work Australia 2013b), and on other related exposure control requirements and approaches relevant to PAHs (Safe Work Australia 2011b; 2012a; 2013a; 2013c).

2. Victoria and Western Australia have not adopted the model WHS Regulations and specific regulatory requirements in these jurisdictions may differ

METHODS

Australian Workplace Exposure Study

The analysis presented in this report uses AWES data (Carey et al. 2014)[1]. The AWES project is a nationwide survey which investigated the current prevalence of work-related exposure to 38 known or suspected carcinogens including PAHs among Australian workers (Carey et al. 2014).

Study Population

The sample for the AWES was obtained from a commercial survey sampling firm and consisted of household contact details compiled from various public domain data sources such as telephone directories. Both landline and mobile phone numbers were included and the sample was stratified to reflect the approximate distribution of the Australian work force by state and territory as reported by the ABS Labour Force Survey from March 2011 (Australian Bureau of Statistics 2011a). Within these households currently employed residents aged between 18 and 65 were eligible to participate. Those with insufficient English language ability and those who were too ill to participate were ineligible. One eligible person within each household was selected for interview.

Of the 19 896 households telephoned during the course of this study, 2452 did not respond, 10 485 were ineligible, and 1936 refused to participate. Five thousand and twenty-three interviews were completed and the response rate (excluding ineligible households) was 53%.

Data Collection

Interviews commenced in October 2011 and were completed in late 2012. All interviews were conducted by trained interviewers using computer-assisted telephone interviews. Respondents provided oral informed consent prior to any data being collected. Demographic information collected included age, gender, postcode of residence, country of birth, language spoken at home, and highest level of education.

The respondent's main job was then categorised as either exposed or unexposed to any of the 38 carcinogens by the use of a simple screening tool. Respondents whose job fitted into one of 13 predetermined categories of unexposed jobs such as white-collar professional or customer service were classified as unexposed and their interview completed. A total of 2532 respondents were categorised as unexposed at this point (minimal information was collected on these persons). Basic job information such as job title, main tasks at work, industry, frequency of work in terms of hours per week and weeks per year was then collected from the remaining 2491 respondents with the aim of using this information to assign them to one of 58 job specific modules (JSMs). These modules included questions about

1. A detailed overview of the AWES study and the prevalence of exposures to the 38 carcinogens has been published—see Carey, R, Driscoll, T, Peters, S, Glass, D, Reid, A, Benke, G, et al. (2014). Estimated prevalence of exposure to occupational carcinogens in Australia (2011-2012). Occupational and Environmental Medicine, 71(1):55-62. This section of the report summarises the research methodology

the completion of tasks likely to involve exposure to carcinogens, and were developed by a team of occupational hygienists and epidemiologists. An example is provided in Appendix 3.

All modules were completed using OccIDEAS (Fritschi et al. 2009), an online tool to manage interviews and exposure assessments, with each full interview taking approximately 15 minutes. Following the interviews, each job was coded according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO) 2006 (Australian Bureau of Statistics 2006) and then categorised into one of 30 occupational groups, with each group containing occupations which were judged to be relatively homogeneous in terms of exposure (Carey et al. 2014). Thirty respondents reported jobs with insufficient information to be classified and were thus excluded from further analysis, resulting in a final sample of 4993 respondents.

Exposure Assessment

Automatic assessments of the probability ('none', 'possible' or 'probable') and level ('low', 'medium', 'high') of exposure to PAHs were provided by OccIDEAS using predetermined rules developed on the basis of expert opinion. These rules were based on occupational hygienists' practical experience of workplace exposures and available exposure measures in the literature. These rules took into account the amount of time spent working on relevant tasks and the use of exposure control measures where this information was available. All automatic assessments were reviewed by project staff for consistency. The assessments were qualitative and referred to:

- exposure levels relevant to suspected carcinogenic outcomes—i.e. they do not necessarily correlate to exposures standards, and
- the level of exposure while undertaking the relevant task—they are not an assessment of the time-weighted average exposure of that person.

Two thousand, four hundred and ninety-one respondents completed a JSM. Twenty-two of these modules (and two additional sub-modules) included questions relevant to exposures to PAHs such as being exposed to smoke in various circumstances such as fire fighting and burn offs, and working with asphalt. Two hundred and ninety seven respondents were judged to have probable exposure to PAHs in their current occupation.

Statistical Analysis

All statistical analyses were conducted using SAS version 9.3 and Excel. Confidence intervals for proportions were also calculated using an on-line tool (Lowry 2013). Only those persons designated as having probable work-related exposure to PAHs were included in the main analysis. Assessments were extrapolated with reference to the 2011 Census (Australian Bureau of Statistics 2011b) to calculate an estimate of the number of Australian workers currently exposed to PAHs in the course of their work. These extrapolations were stratified by gender and conducted separately by occupational group in order to account for potential differences in exposure. The results are presented in text, figures and tables. The main body of

the report has primarily text and figures. Most of the tables are included in Appendix 4. Confidence intervals are not included in the figures and text for ease of understanding but, where appropriate, are included in the tables. Categories with less than three subjects are not separately described or presented.

RESULTS: Information on exposure and control measures from the Australian Workplace Exposure Study

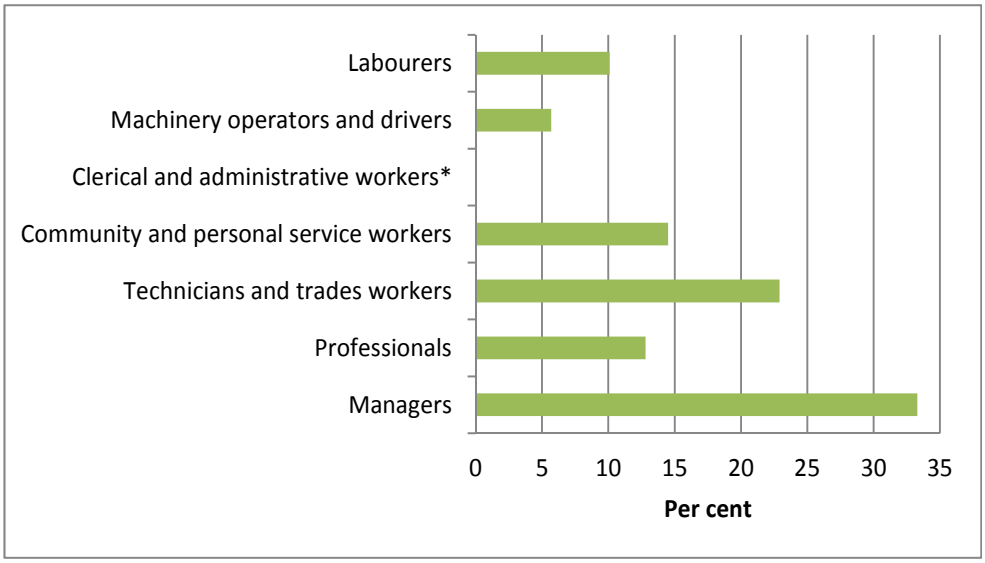
Overall results

Of the 4993 respondents with useable data, 297 (5.9%) had probable exposure to PAHs. This was 8.6% of males and 2.6% of females in the study. Two hundred and thirty-nine (80.5%) exposed respondents were male and the remaining 58 (19.5%) were female.

Among those exposed the level of exposure was deemed to be high for 127 (42.8%), medium for 60 (20.2%) and low for 110 (37.0%).

One third (99, 33.3%) of the exposed respondents worked as managers (mainly farmers), with another 68 (22.9%) working as technicians or trades workers and 43 (14.5%) as community and personal service workers (Figure 1)[1].

Figure 1: Occupation of all respondents exposed to PAHs—per cent

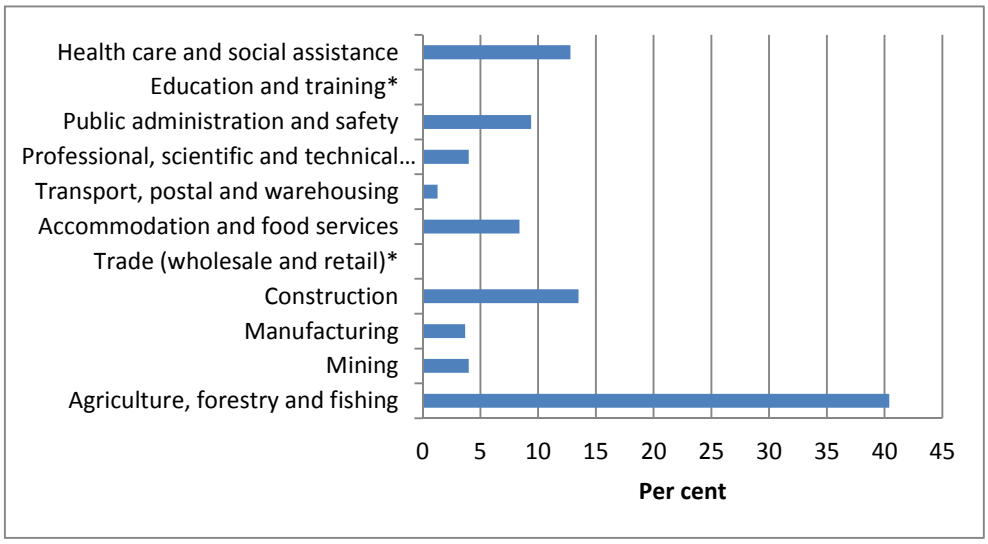


* This category had at least one but less than three subjects.

Agriculture was the most common industry of employment of exposed respondents (118, 39.7%), with Construction (40, 13.5%) and Health care and social assistance (38, 12.8%) the next highest-represented industries (Figure 2).

1. Tables providing data on which Figures are based are in Appendix 3.

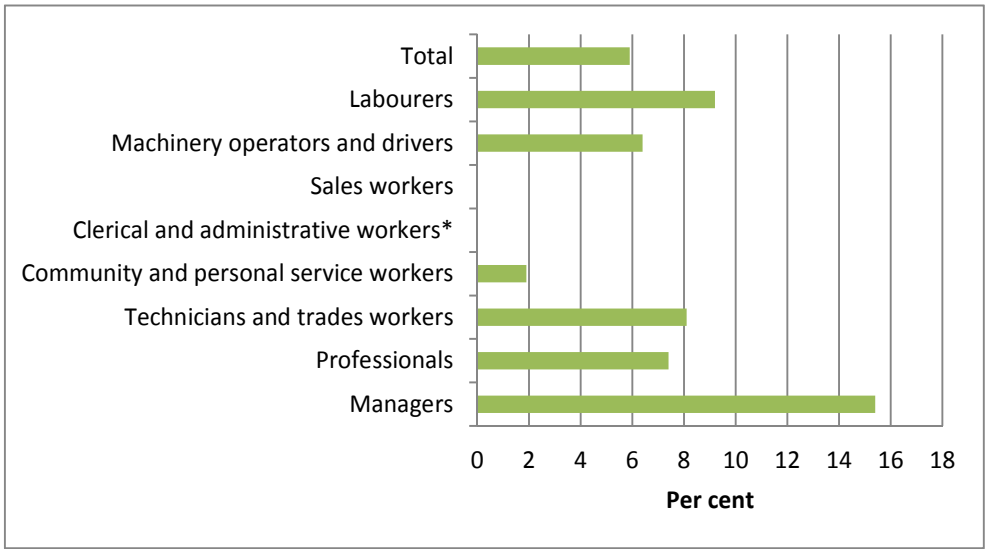
Figure 2: Industry of all respondents exposed to PAHs—per cent



* These categories had at least one but less than three subjects.

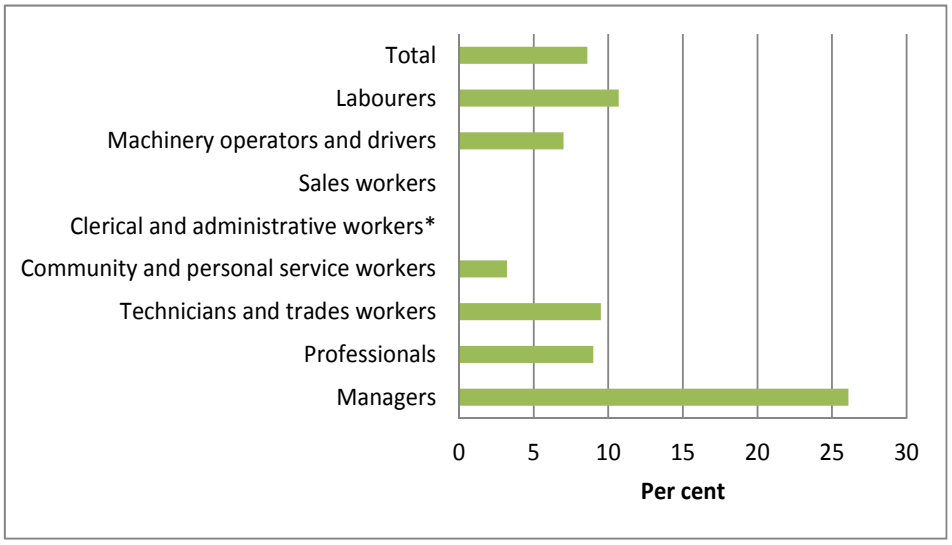
The proportion of respondents within a given occupation or industry who were exposed to PAHs was estimated by dividing the number of exposed respondents in a given occupation or industry by the total number of AWES respondents within that occupation or industry. Occupations with the highest proportion of respondents exposed were managers (15.4%), labourers (9.2%) technicians and trades workers (8.1%), professionals (7.4%) and machinery operators and (6.4%). The occupations with the highest prevalence of exposure were similar for male respondents (Figures 3 and 4).

Figure 3: Proportion of all respondents in each occupation who were exposed to PAHs—per cent



* This category had at least one but less than three subjects.

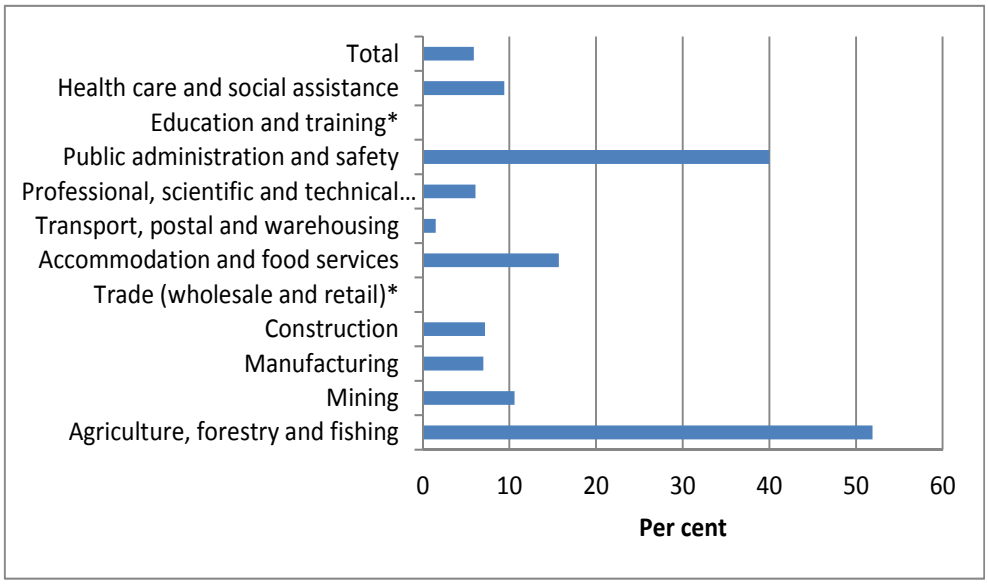
Figure 4: Proportion of male respondents in each occupation who were exposed to PAHs—per cent



* This category had at least one but less than three subjects.

In the Agriculture industry about half the people were exposed (51.1%). Other industries with high proportions of persons exposed were Public administration and safety —i.e. firefighters[2]—(32.9%), Accommodation and food services (15.7%), Mining (9.7%) and Health care and social assistance (9.4%). The industries with the highest prevalence of exposure were similar for men (Figures 5 and 6).

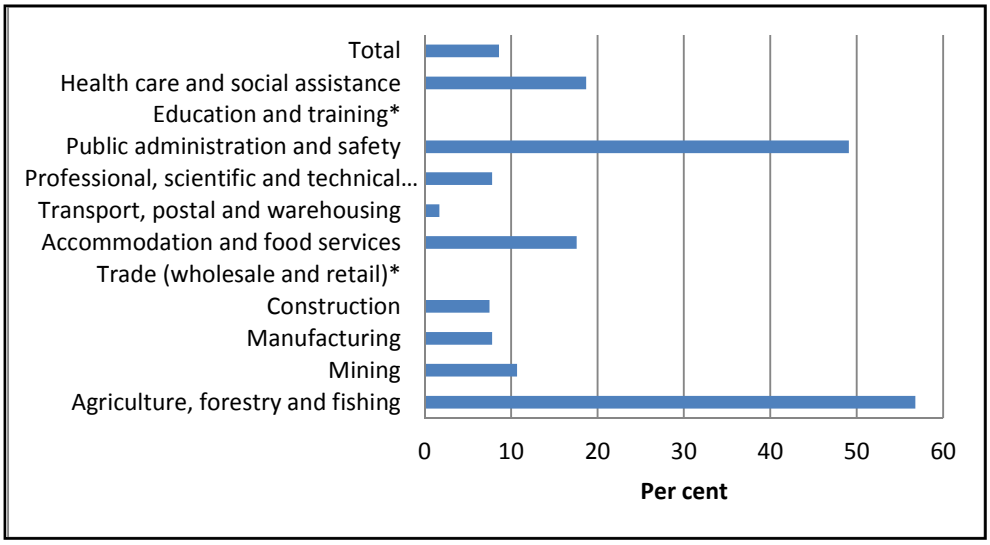
Figure 5: Proportion of respondents in each industry exposed to PAHs—percent



* This category had at least one but less than three subjects.

2. This industry classification includes Australian Defence Force personnel, and public order, safety, and regulatory services staff like fire fighters

Figure 6: Proportion of male respondents in each industry exposed to PAHs—per cent



* This category had at least one but less than three subjects.

The prevalence of exposure to PAHs in the Australian workforce

Using 2011 Census data (Australian Bureau of Statistics 2011b) and the estimated proportions of respondents exposed in each major occupation group, stratified by gender, the numbers of exposed Australian workers in each major occupation group and overall were estimated and are presented in Table 1. Estimates are only provided for groups with at least three exposed persons in the study population.

These estimates suggest about 675 000 Australian workers, or 6.7% of the workforce, are probably exposed to PAHs when undertaking relatively common activities at work. This is overall. The exposure occurs predominantly in men. Approximately 550 000 men or 10.3% of the male workforce and approximately 125 000 women or 2.7% of the female workforce are estimated to be exposed.

Table 1: Estimated number of Australian workers exposed to PAHs—by occupation.

Occupation[1]	Male	95% CI[2]	Female	95% CI	Total	95% CI
Managers	217 990	178 000–263 000	25 867	16 000–40 000	243 856	200 000–292 000
Professionals	89 252	59 000–133 000	66 944	39 000–111 000	156 197	113 000–213 000
Technicians and trades workers	115 540	90 000–147 000	8193	4000–16 000	123 732	97 000–156 000
Community and personal service workers	9643	7000–14 000	5905	3000–11 000	15 547	11 000–21 000
Clerical and administrative workers[3]	-	-	-	-	-	-
Machinery operators and drivers[3]	41 407	25 000–66 000	-	-	41 407	25 000–66 000
Labourers	65 411	44 000–95 000	18 426	7000–43 000	83 837	58 000–119 000
Total[4]	551 484	487 000–623 000	125 335	96 000–162 000	676 819	605 000–757 000

Notes:

1: There was at least one person from the clerical and administrative workers occupation category. Estimates are not provided for this occupation category as there were less than three exposed persons in the study population. There were no exposed persons from occupation categories not included in the table.

2: 95% confidence interval.

3: There were no female clerical and administrative workers or machinery operators and drivers in the AWES study who were deemed exposed to PAHs.

4: The total is greater than the sum of the columns because estimates are not included in the table for those occupations with insufficient subjects (identified with '-' in the column).

Circumstances of exposure

The assessed PAHs exposure occurred in a variety of circumstances. The main exposure circumstances are summarised in Table 2. The main exposure circumstances were exposure to smoke through burning waste, fighting fires or through maintaining mowers or other equipment[3] (an exposure mainly identified in farmers). Other common exposure circumstances were cleaning up ash after a fire, health workers exposed to diathermy smoke (smoke arising from cauterisation during surgery), cooking, and welding surfaces with a coating. Some respondents had more than one exposure circumstance and some less common exposure circumstances are not included in Table 2.

Table 2: Main circumstances resulting in exposure to PAHs.

Exposure circumstance	High	Medium	Low	Total
Burning waste	78	14	-	92
Cleaning out ash	36	1	-	37
Fighting fires and fire overhaul	12	9	-	21
Miners with ammonium nitrate fuel oil	6	-	-	6
Using asphalt or tar	1	4	4	9
Repairing motors	-	75	-	75
Working with creosote-treated wood	-	3	6	9
Health workers with diathermy	-	-	37	37
Cooking	-	-	28	28
Welding material with a coating	-	-	17	17
Firing range	-	-	12	12

Note: This table does not include all exposed persons and persons could be exposed through more than one activity.

The main circumstances resulting in assessed **high** exposures were:

- fire fighters fighting fires or engaged in fire overhaul and clean-up or back-burning without consistent use of breathing apparatus
- farmers involved in burning waste in the open, and often also cleaning ash left from burning waste
- forestry workers involved in back burning
- gardeners burning waste and sometimes cleaning ash left from burning waste
- miners using ammonium nitrate fuel oil (exposed to fumes from explosion), and
- metal workers cleaning out ash or scale from a furnace.

The main circumstances resulting in assessed **medium** exposures were:

- fire fighters fighting fires or engaged in fire overhaul and clean-up or back-burning with consistent use of breathing apparatus
- farmers involved in burning waste in an incinerator or drum
- farmers exposed to engine exhaust fumes when maintaining mowers or other equipment
- road workers using a hot mix of asphalt
- carpenters applying creosote to wood, and

3. AWES respondents were asked “Do you repair or maintain power mowers or other equipment?” Additional questions about the type of equipment were not asked.

- police officers involved occasionally in attending fires.

The main circumstances resulting in assessed **low** exposures were:

- carpenters working with wood treated with creosote
- chefs involved in various forms of cooking
- health workers exposed through diathermy
- lab workers undertaking tests on hydrocarbons
- road workers using a cold mix of asphalt, and
- welding materials with a coated surface.

Each of the main tasks involving PAHs exposure is considered in more detail below.

Burning waste

There were 92 respondents exposed to PAHs from burning waste—77 farmers, 11 gardeners, three forestry workers involved in back burning and a labourer. Fourteen farmers burned waste in an incinerator or drum and were deemed to have medium exposure from this activity. The remaining respondents were deemed to have high exposure from this activity.

Maintaining power mowers or other equipment

Seventy-five farmers were deemed to have medium exposure to PAHs from exposure to engine exhaust fumes through repairing or maintaining power mowers or other equipment.

Fire fighting, fire overhaul and clean-up, and back-burning

There were 21 fire fighters deemed to have probable exposure to PAHs as a result of fire fighting, 18 of whom also undertook overhaul, clean up, or sifting through the remains of a fire and 11 who were also involved in back-burning. Nineteen were career fire fighters and the other two were volunteers. On the basis of their fire-fighting activities and pattern of use of breathing apparatus, 12 were deemed to have high exposure to PAHs and nine were deemed to have medium exposure.

Removing or cleaning out the ash from fire sites

Thirty-seven respondents were deemed to be exposed to PAHs when removing or clearing out ash from fire sites. Most respondents were farmers who had also been involved in burning waste or back burning. The remaining respondents were metal workers who cleaned out ash or scale from furnaces. One metal worker was deemed to have medium exposure to PAHs rather than high exposure because they used respiratory protective equipment.

Cooking

Twenty-eight respondents were deemed to be exposed to PAHs when cooking (25) or food processing (3) during tasks which involved frying, cooking in a wok or using a wooden stove. All were deemed to have low exposure.

Welding material with a coating

Seventeen respondents, most in the Construction industry, were deemed to have low exposure to PAHs when welding materials with coated surfaces.

Diathermy

Thirty-seven health workers were deemed to have low exposure to PAHs when exposed to smoke arising from cauterisation during surgical operations.

Working with asphalt or tar

Nine respondents were exposed to PAHs when exposed to asphalt or tar. Eight of these respondents were involved in road construction. Four were deemed to have medium exposure as they used hot mix and four were deemed to have low exposure as they used cold mix (which is associated with a lower level of fumes and thus lower exposure to PAHs). The ninth respondent was deemed to have high exposure when using asphalt, tar and bitumen for railway work.

Working with creosote

Nine carpenters were exposed to PAHs when working with creosote or creosote-treated wood. Three were deemed to have medium exposure because they applied creosote to the wood and the other six were deemed to have low exposure because they only worked with creosote-treated timber.

Miners

Six miners were deemed to have high exposure to PAHs arising from exposure to blasting fumes through their use of ammonium nitrate fuel oil in their mining work.

Firing range

Twelve people, six from the military and six from the police force, were deemed to have low exposure to PAHs when instructing or practicing firing a gun at an indoor firing range.

Other exposure circumstances

Other circumstances of exposure to PAHs included:

- electricians applying asphalt coating to cables
- lab workers testing hydrocarbons, and
- workers involved in aluminium smelting.

The use of respiratory protection equipment

There was little or no information on the use of respiratory protective equipment or skin protection for many of the main circumstances involving exposure to PAHs. However, information was available for fire fighting, back burning and welding.

Twenty-one fire fighters were deemed to have been exposed on the basis of this fire fighting, primarily through front-line fire-fighting, fire overhaul and clean-up, or back-burning. Of these, eight (38%) reported always and eight (38%) reported usually wearing breathing apparatus while fighting fires.

The remaining five (24%) sometimes or never used breathing apparatus. Of the 18 fire fighters involved in fire overhaul and clean-up, five (28%) always and six (33%) usually used breathing apparatus. Five sometimes (28%) and two never (11%) used breathing apparatus while involved in fire overhaul and clean-up. Eleven fire fighters reported being involved in back burning. Seven (64%) never, three (18%) sometimes and one (9%) always used breathing apparatus. Taking all activities into account, nine fire fighters (42.9%) always or usually used breathing apparatus while undertaking all fire fighting activities and 12 fire fighters (57.1%) never or only sometimes used breathing apparatus. Of the three forestry workers involved in back burning, none used respiratory protective equipment.

Seventeen welders were exposed to PAHs when welding materials with coated surfaces:

- five reported usually using an air-supplied welding helmet
- twelve reported they used a welding booth but 11 of these said they used the booth less than half the time they welded
- twelve reported welding outdoors at least some of the time but eight of these did so less than half the time, and
- four reported welding in confined spaces, all of whom reported they did not use an air-supplied welding helmet.

DISCUSSION AND INTERPRETATION OF THE STUDY FINDINGS

Exposures

The main circumstances of exposure to PAHs identified in the AWES project were exposure to smoke through burning or fighting fires and exposure to engine exhaust fumes when doing maintenance work on mowers or other equipment. Other common exposure circumstances were cleaning up ash after a fire, exposure to diathermy smoke during surgery, cooking, and welding materials with coated surfaces. These exposure circumstances cover many of those traditionally associated with PAHs exposure. However, some industries or occupations that may be traditionally associated with exposures to PAHs may not be included in the AWES data set. This is because AWES is not a study of specific industries but is a population-based study that attempts to identify if exposures to PAHs occur in the course of general work activities. These are two very different areas, although clearly with some overlap. This is an unavoidable aspect of any such large scale survey. Studies such as AWES are not designed to provide detailed information about exposure circumstances in a specific industry sector known to have PAHs exposure. That information can be obtained much more efficiently from a small study designed specifically to provide such information. Instead, AWES indicates that PAHs exposure is common in a range of occupations and industries.

Qualitative information on exposure was collected, based on job tasks. This approach should have provided a good qualitative understanding of exposures but there is no scope in the current design to validate the estimates by taking quantitative measures in workplaces. Nevertheless, the questions asked and the coding logic of the AWES database are based on published studies that provide semi-quantitative estimates of PAHs exposure.

Based on AWES results and national employment data, it is estimated that about 675 000 workers—approximately 6.7% of the Australian workforce—are likely to be exposed to PAHs at least some of the time in their current job. The exposure prevalence was higher in men (10.3%) than women (2.7%), presumably reflecting that a higher proportion of men than women work in occupations and industries where PAHs exposure is more likely. Many occupational circumstances involve exposures to PAHs. Some individual PAHs are known human carcinogens and others are probable human carcinogens which means that exposure should be minimised to as low a level as reasonably practicable.

The exposure prevalence in this study was higher than that found in the 0.7% exposure prevalence found in the CAREX study (Finnish Institute of Occupational Health 1998) and the 2% exposure prevalence found in the CAREX Canada study (CAREX Canada 2014). However, many of the occupations and industries with higher exposure prevalence were similar between the studies. Some of the differences in the prevalence estimates between the three studies probably reflect the different industry proportions in the countries in which the three studies were based. The studies also used quite different methods, AWES being the only study that surveyed

workers about what tasks they actually performed at work and took into account the use or non-use of control measures. CAREX estimates and CAREX Canada estimates were based on workplace measures taken for a range of reasons and on expert opinion. The definition of exposure in the studies also appears to have been different although it is difficult to make a direct comparison. It may also be that the AWES project accepted lower exposures or a lower probability of exposure in exposed subjects than did the other two studies. The level of exposure in the AWES project was based on exposure while undertaking the relevant task and was not intended to necessarily relate to an assessment of the time-weighted average exposure of that person. The definition of what is high, medium and low exposure is certainly important but was only possible in a qualitative sense. The methods used in the AWES project suggest it is more likely to provide a nationally representative estimate of exposure than are the other two studies. However, the other two studies did, to some extent, incorporate levels of workplace exposure estimates as part of their methodology.

Use of control measures

There was not a lot of information on the use of control measures for many of the PAHs exposure circumstances considered in AWES but information was available for fire fighting, back burning and welding. The analysis of available AWES data showed inconsistent use of control measures in circumstances that entailed probable exposure to PAHs. The control measures such as breathing apparatus, supplied-air respirators and welding booths used by respondents related to decreasing the chance of inhalation. Where information was available it suggested respiratory protection was commonly (by more than half the respondents) not used effectively, either because it was not used appropriately when it was used or it was used for less than half the time respondents were exposed.

Gaps, strengths and weaknesses

This report focuses primarily on data from the AWES project mainly because there are few other relevant data sources available. The AWES project provides the first nationally representative information on current workplace exposure to a range of definite and probable carcinogens. It also provides evidence on which to base estimates of future burden arising from exposures and estimates of future avoidable burden if exposures are better controlled. This information can be used for prioritising work to decrease exposures to PAHs. However, like any such survey it is has some limitations.

Data were collected through a telephone survey, with attendant time restraints in terms of maintaining the respondent's cooperation. In practical terms telephone-based surveys involve a compromise between covering the essential questions and including questions that are important but not required for the primary purpose of the study. As the AWES covered a range of potential exposures a limited number of specific questions could be asked about any particular exposure. There were similar issues with the NHEWS project.

The sample was selected to be representative of the workforce, and the occupation and industry within the workforce, of each State and Territory and therefore of the national workforce. The final sample on whom the results are based may not have been fully representative of the workforce due to people declining to be interviewed or being ineligible, but it was known that most of the general characteristics were similar between the final included sample and the general Australian population of working age. The primary study results of prevalence of exposure in the Australian workforce are based on the prevalence of exposure in the occupations that had the possibility of being exposed. This provided information on the prevalence of exposure to each carcinogen of interest in each occupation. This information was extrapolated to the Australian workforce, taking into account (that is, weighting by) the occupational distribution. If there is error in these prevalence estimates, it will have come primarily because certain specific occupations in a broader occupation group were not accurately represented in the sample because a higher proportion of their members declined to be included or were ineligible—e.g. because they did not speak English—and/or because those who participated did not accurately report their exposure.

The study relied on self-report data, which is likely to introduce some error into the exposure assessment. However, the exposure assessment relied on subjects describing their current job tasks, guided by the questions in the relevant job-specific modules, rather than the workers having to recognise and recall specific exposures. This makes it less likely that exposure will be missed and less likely that specific exposures will be erroneously reported (Parks et al. 2004).

As a population-based study, AWES can only expect to provide representative exposure information on relatively common activities. Information will be lacking on most industry sub-sectors, specific occupations and specific tasks which are less common or which are undertaken by a relatively small number of people. This is why tasks that would usually be viewed as having a high prevalence of PAHs exposure were not included in the study sample. If detailed information is required about a specific sector of the workforce or a specific activity, this would require a targeted, specific research project to be undertaken.

As noted previously, exposure assessments were qualitative and referred to:

- exposure levels relevant to suspected carcinogenic outcomes—i.e. they do not necessarily correlate to airborne exposure standards, and
- the level of exposure whilst undertaking the relevant task—i.e. they are not an assessment of the time-weighted average exposure of that person.

The AWES project provided some information on the use of control measures, but the information that could be collected in this area was somewhat limited. The questions asked in AWES were aimed primarily to allow assessment of the fact of exposure and if possible, the level of exposure.

Non-response is also an issue for any survey approach such as that used

for AWES. This raises the possibility that those who did participate had a different prevalence of exposure and a different approach to the use of exposure control measures than those who did not participate. Since there is no employment information available on the people who did not participate, it is not possible to assess this potential problem in detail.

There is uncertainty in the estimated overall number of workers exposed to PAHs. This is because the number of exposed respondents was low in some gender-specific and occupation-specific groups, meaning the estimate for that group had considerable uncertainty. The overall estimate based on occupation is likely to be reasonably accurate, and the confidence intervals around the estimates give a guide as to the likely range in which the true value probably lies.

Policy implications

This study estimated approximately 6.7% of the Australian workforce is likely to be exposed to PAHs when performing relatively common activities at work. The estimated prevalence is higher than results of some other studies. As noted, the differences probably reflect differences in the industry distribution and in the methodology used in the various studies, with the AWES using a task-based assessment process.

The probability of any increased risk of work-related cancer in exposed workers will depend on the type of cancer and the level, duration and frequency of exposure. Since many PAHs are known or probable carcinogens, exposure to PAHs must be minimised to as low a level as is reasonably practicable.

In general, some of the health risks posed by exposures to PAHs, the tasks that might result in such exposures and the methods of preventing exposure should be well understood by employers and workers, but circumstances such as exposure to smoke and ash in many circumstances, and exposure during maintenance of motors, may not be properly appreciated. However, the inconsistency in cancer classifications between some authoritative sources could create uncertainty about the risks posed by PAHs exposures. While outside the scope of this report, future work could consider if revising the current classification information in HSIS is warranted based on the recent work of the IARC.

The use of controls by workers in the AWES sample was not good. Where information on the use of controls was collected, less than half of respondents reported using what appeared to be adequate respiratory protective measures and many reported not using any controls to prevent exposures. There is an opportunity to prevent and to decrease work-related exposures to PAHs, and thereby reduce the potential for work-related cancer cases, through efforts to increase the number of workplaces that eliminate exposure to PAHs where possible or consistently use high order controls and good work practices to eliminate or reduce exposures to PAHs when relatively common activities are carried out. This may simply require initiatives that raise awareness or educate PCBUs and workers about known controls to prevent or minimise exposures to PAHs. In particular, efforts could be focused on lowering exposures in those activities where a significant number of workers were assessed as having high or medium exposures in the AWES and ensuring that exposed workers are supplied

with and use appropriate respiratory protective equipment. Examples of these circumstances include workers involved in:

- burning waste
- cleaning ash from fire sites
- fighting fires or undertaking fire overhaul and clean up
- preparing and using ammonium nitrate fuel oil, and
- road building with hot asphalt road mix.

Initial efforts could focus on initiatives that raise awareness or educate PCBUs and workers about minimising exposure to PAHs and using well-known and readily available controls to decrease exposures to PAHs.

Research opportunities

Exposures

The AWES project provides qualitative information on current exposures to PAHs based on job tasks. Quantitative measures of PAHs exposure in the workplace may be of use to validate the data collected in AWES and to help better understand the absolute levels of exposure to PAHs. There was no scope to do this as part of the AWES but this information would be useful for the tasks identified in the AWES analysis.

The use of control measures

The collection of more detailed information on the use of control measures should be considered in those work situations highlighted in this report where probable PAHs exposures were assessed as being high or medium. It would also be helpful to understand why appropriate control measures are not used where they should be. Work health and safety policy-makers and practitioners might be interested in aspects like identifying the extent to which:

- PCBUs and workers understand the hazards and associated potential risks
- PCBUs and workers understand the need for various control measures and how they operate
- higher order controls are used
- current regulations and guidance are adequate for preventing exposures, and
- current methods for providing risk management information and assistance to PCBUs are effective.

This information would allow interventions and prioritisation of action to be based on sound evidence from Australian workplaces.

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GLOSSARY

95% CI	95% confidence interval
ABS	Australian Bureau of Statistics
ANZSCO	Australian and New Zealand Standard Classification of Occupations
Approved Criteria	Approved Criteria for Classifying Hazardous Substances [NOHSC:1008(2004] 3rd Edition
AWES	Australia Workplace Exposure Study
CAREX	Carcinogen Exposure (study)
IARC	International Agency for Research on Cancer
JSM	Job-specific module
NHEWS	National Hazard Exposure Worker Surveillance (study)
NICNAS	National Industrial Chemical Notification and Assessment Scheme
NTP	National Toxicity Program
OccIDEAS	An online tool to manage interviews and exposure assessments
PCBU	Persons conducting a business or undertaking
WHO	World Health Organization
WHS	Work health and safety

APPENDIX 1: Classification of carcinogens

IARC classification of carcinogens

The following information is taken from the IARC web site describing the IARC classification.

Group 1	The agent is carcinogenic to humans.
Group 2A	The agent is probably carcinogenic to humans.
Group 2B	The agent is possibly carcinogenic to humans.
Group 3	The agent is not classifiable as to its carcinogenicity to humans.
Group 4	The agent is probably not carcinogenic to humans.

US NTP Classifications

Agents, substances, mixtures, or exposures, collectively called substances, can be listed in the US NTP Report on Carcinogens, either as:

- known to be a human carcinogen, or
- reasonably anticipated to be a human carcinogen.

Further details about listing criteria are available on the US NTP website.

Approved Criteria Classifications

The Approved Criteria for Classifying Hazardous Substances [NOHSC:1008(2004)] (the Approved Criteria) uses the following classification categories for carcinogens:

Category 1	Substances known to be carcinogenic to man.
Category 2	Substances that should be regarded as if they are carcinogenic to man.
Category 3	Substances that cause concern for man owing to possible carcinogenic effects.

APPENDIX 2: Classification of some exposure circumstances and some specific PAHs

IARC classifies some PAH exposure circumstances as follows:

Group 1 — Exposures during:

- coal gasification
- coke production
- coal-tar distillation
- paving and roofing with coal-tar pitch
- aluminium production

Exposure as a chimney sweep

Group 2A — Exposures during carbon electrode manufacture

Group 3 — Exposures during calcium carbide production

Individual PAHs have been classified by IARC, the NTP and are listed in HSIS as shown in Table 3.

Table 3: Classification and HSIS listings for some individual PAHs

Chemical Abstract Service No.	Name	Carcinogen Classification		
		IARC	NTP	HSIS
n.s.	Creosotes	2A		
50-32-8	Benzo[a]pyrene	1	RA	2
27208-37-3	Cyclopenta[cd]pyrene	2A		
50-70-3	dibenz[a,h]anthracene	2A	RA	2
191-30-0	dibenzo[a,l]pyrene	2A	RA	
202-33-5	Benz[j]aceanthrylene	2B		
56-55-3	benz[a]anthracene	2B	RA	2
205-99-2	benzo[b]fluoranthene	2B	RA	2
205-82-3	benzo[j]fluoranthene	2B	RA	2
207-08-9	benzo[k]fluoranthene	2B	RA	2
195-19-7	benzo[c]phenanthrene	2B		
218-01-9	chrysene	2B		2
189-64-0	dibenzo[a,h]pyrene	2B	RA	
191-30-0	dibenzo[a,i]-pyrene	2B	RA	
193-39-5	indeno[1,2,3-cd]pyrene	2B		
3697-24-3	5-methylchrysene	2B	RA	
83-32-9	acenaphthene	3		
191-26-4	anthanthrene	3		
120-12-7	anthracene	3		
202-94-8	11H-benz[bc]aceanthrylene	3		
211-91-6	benz[l]aceanthrylene	3		
214-17-5	benzo[b]chrysene	3		
196-78-1	benzo[g]-chrysene	3		
203-33-8	benzo[a]fluoranthene	3		

Chemical Abstract Service No.	Name	Carcinogen Classification		
		IARC	NTP	HSIS
203-12-3	benzo[ghi]fluoranthene	3		
238-84-6	benzo[a]fluorene	3		
243-17-4	benzo[b]fluorene	3		
205-12-9	benzo[c]fluorene	3		
191-24-2	benzo[ghi]perylene	3		
192-97-2	benzo[e]pyrene	3		
191-07-1	coronene	3		
202-98-2	4H-cyclopenta-[def]chrysene	3		
7099-43-6	5,6-cyclopenteno-1,2-benzanthracene	3		
215-58-7	dibenz[a,c]anthracene	3		
224-41-9	dibenz[a,j]-anthracene	3		
5385-75-1	dibenzo[a,e]fluoranthene	3		
207-83-0	13H-dibenzo[a,g]fluorene	3		
192-47-2	dibenzo[h,rst]pentaphene	3		
192-65-4	dibenzo[a,e]pyrene	3	RA	
192-51-8	dibenzo[e,l]pyrene	3		
641-48-5	1,2-dihydroaceanthrylene	3		
22349-59-3	1,4-dimethylphenanthrene	3		
206-44-0	Fluoranthene	3		
86-73-7	Fluorene	3		
3351-28-8	1-methylchrysene	3		
3351-32-4	2-methylchrysene	3		
3351-31-3	3-methylchrysene	3		
3351-30-2	4-methylchrysene	3		
1705-85-7	6-methylchrysene	3		
33543-31-6	2-methylfluoranthene	3		
1706-01-0	3-methylfluoranthene	3		
832-69-9	1-methylphenanthrene	3		
111189-32-3	naphtho[1,2-b]fluoranthene	3		
203-20-3	naphtho[2,1-a]-fluoranthene	3		
193-09-9	naphtho[2,3-e]pyrene	3		
198-55-0	perylene	3		
85-01-8	phenanthrene	3		
213-46-7	picene	3		
129-00-0	pyrene	3		
217-59-4	triphenylene	3		
226-36-8	dibenz[a,h]acridine		RA	
224-42-0	dibenz[a,j]acridine		RA	
194-59-2	7H-dibenzo[c,g]carbazole		RA	
193-39-5	indeno[1,2,3-cd]pyrene		RA	

n.s. not specified

APPENDIX 3: Relevant questions and exposure coding rules for example Job-Specific Modules

Job-specific module for fire fighting

What activities do you mainly perform as a fire fighter?

- frontline fire fighting
- search and rescue including motor vehicle accidents
- respond to Incidents involving hazardous materials
- natural disaster response
- overhaul, clean up, and/or sifting through the remains of a fire
- support, education, prevention, communications, or management activities
- other, please specify

How often do you wear breathing apparatus during frontline fighting?

- always
- more than 50% of the time
- less than 50% of the time
- never

How often do you wear breathing apparatus during overhaul or clean up?

- always
- more than 50% of the time
- less than 50% of the time
- never

Are you involved in back burning, controlled burning, or preventative burning?

How often do you wear breathing apparatus when back burning?

- always
- more than 50% of the time
- less than 50% of the time
- never

For overall or clean up or back burning, code as **high** exposure if BA [breathing apparatus] used less than 50%; code as **medium** if BA used more than 50% of the time or always.

Job-specific module for road construction

Do you work with hot or cold mix asphalt? [allow multiple]

- hot mix
- cold mix
- other, please describe [free text]

Code as **medium** exposure if hot mix; code as **low** exposure if cold mix.

APPENDIX 4: Tables relevant to Figures presented in Chapter 3

Table 4: Occupations of all PAH-exposed persons—numbers and percentages

Occupation	Number	Per cent
Managers	99	33.3
Professionals	38	12.8
Technicians and trades workers	68	22.9
Community and personal service workers	43	14.5
Clerical and administrative workers1	-	-
Machinery operators and drivers	17	5.7
Labourers	30	10.1
Uncertain[1]	-	-
Total[2]	297	100.0

Notes:

1: There was at least one person from the clerical and administrative workers occupation category and one person with uncertain occupation. Numbers and percentages for this are not shown because there were less than three persons in the category. There were no exposed persons from other occupation categories not shown.

2: Numbers do not add to the total (nor percentages to 100) because subjects from the clerical and administrative workers occupation category or with unknown occupation are not included in the table.

Table 5: Industries of all PAH-exposed persons—numbers and percentages

Industry	Number	Per cent
Agriculture, forestry and fishing	120	40.4
Mining	12	4.0
Manufacturing	11	3.7
Construction	40	13.5
Trade (wholesale and retail)[1]	-	-
Accommodation and food services	25	8.4
Transport, postal and warehousing	4	1.3
Professional, scientific and technical services	12	4.0
Public administration and safety	28	9.4
Education and training[1]	-	-
Health care and social assistance	38	12.8
Uncertain	4	1.3
Total[2]	**297**	**100.0**

Notes:

1: There was at least one person from each of the trade and the education and training industry categories. Numbers and percentages for these are not shown because there were less than three persons in each category. There were no exposed persons from other industry categories not shown.

2: Numbers do not add to the total (nor percentages to 100) because subjects from the trade and the education and training industry categories or with uncertain industry are not included in the table.

Table 6: Proportions of respondents in each occupation who were exposed to PAHs—per cent

Occupation	Male	Female	Total
Managers	26.1	5.7	15.4
Professionals	9.0	5.8	7.4
Technicians and trades workers	9.5	3.9	8.1
Community and personal service workers	3.2	0.9	1.9
Clerical and administrative workers	3.5	-	2.4
Machinery operators and drivers	7.0	-	6.4
Labourers	10.7	5.5	9.2
Total	**8.6**	**2.6**	**5.9**

Note: There was at least one person from the clerical and administrative workers occupation category. Percentages for this category are not shown because there were less than three persons in the category. There were no exposed persons from other occupation categories not shown.

Table 7: Proportions of respondents in each industry who were exposed to PAHs—per cent

Industry	Male	Female	Total
Agriculture, forestry and fishing	56.8	36.4	51.9
Mining	10.7	10.0	10.6
Manufacturing	7.8	0.0	7.0
Construction	7.5	0.0	7.2
Trade (wholesale and retail)	1.8	0.0	1.1
Accommodation and food services	17.6	14.1	15.7
Transport, postal and warehousing	1.7	0.0	1.5
Professional, scientific and technical services	7.8	3.7	6.1
Public administration and safety	49.1	11.8	40.0
Education and training	0.0	4.3	2.2
Health care and social assistance	18.7	6.1	9.4
Total	**8.6**	**2.6**	**5.9**

Note: There was at least one person from of the trade (wholesale and retail) and the education and training industry categories. Percentages for these categories are not shown because there were less than three persons in each of the categories. There were no exposed persons from other industry categories not shown.