The Australian Work Exposures Study: Occupational exposure to polycyclic aromatic hydrocarbons

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ABSTRACT

Introduction

The aims of this study were to produce a population-based estimate of the prevalence of work-related exposure to polycyclic aromatic hydrocarbons (PAHs), to identify the main circumstances of exposure, and to describe the use of workplace control measures designed to decrease those exposures.

Methods

The analysis used data from the Australian Workplace Exposures Study, a nationwide telephone survey which investigated the current prevalence and exposure circumstances of work-related exposure to 38 known or suspected carcinogens, including PAHs, among Australian workers aged 18 to 65 years. Using the web-based tool OccIDEAS, semi-quantitative information was collected about exposures in the current job held by the respondent. Questions were addressed primarily at tasks undertaken rather than about self-reported exposures.

Results

297 (5.9%) of the 4,993 included respondents were identified as probably being exposed to PAHs in their current job (extrapolated to 6.7% of the Australian working population – 677,000 (95% confidence interval 605,000 – 757,000) workers). Most (81%) were male; about one third were farmers and about one quarter worked in technical and trades occupations. In the agriculture industry about half the workers were probably exposed to PAHs. The main exposure circumstances were exposure to smoke through burning, fighting fires or through maintaining mowers or other equipment; cleaning up ash after a fire; health workers exposed to diathermy smoke; cooking; and welding surfaces with a coating. Where information on control measures was available, their use was inconsistent.

Conclusion

Workers are exposed to PAHs in many different occupational circumstances. Information on the exposure circumstances can be used to support decisions on appropriate priorities for intervention and control of occupational exposure to PAHs, and estimates of burden of cancer arising from occupational exposure to PAHs.

Keywords: cross-sectional study; population prevalence; workers, PAH
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INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemical compounds with related structures which are formed during the incomplete combustion of organic material. There are more than a hundred PAH compounds and they typically exist as a complex mixture. Of those PAHs classified by the International Agency for Research on Cancer (IARC), 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). Benzo(a)pyrene is a PAH compound commonly used as marker of overall PAH exposure and is classified as a Group 1 agent by IARC (International Agency for Research on Cancer (IARC) 2010; Straif et al. 2005). The carcinogenicity of PAHs is based on strong evidence that some PAH compounds 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 (IARC) 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" (National Toxicology Program 2011).

Low level exposure to PAHs is very common through environmental and dietary sources (Agency for Toxic Substances and Diseases Registry (ATSDR) 1995; CAREX Canada 2014; International Agency for Research on Cancer (IARC) 2010; Straif et al. 2005). Occupational exposure can occur in a wide variety of exposure circumstances. In terms of tasks associated with PAH exposure, 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) (Straif et al. 2005). Most of these exposure circumstances have been or could be suspected to be relevant to Australian workplaces. There are reports examining aspects of exposure in specific circumstances such as aluminium smelting (Di Corleto 2010; Friesen et al. 2009) and fire fighting (Reisen and Brown 2009; Reisen and Tiganis 2007), but there is no nationally representative or comprehensive information about the nature of this exposure in Australia and limited data on exposures at a population level elsewhere (CAREX Canada 2014; Finnish Institute of Occupational Health 1998; Peters, Ge, et

al. 2015). Such information would help inform efforts to control or prevent occupational exposure to PAHs.

The aims of this study were to produce a population-based estimate of the prevalence of work-related exposure to PAHs, to identify the main circumstances of exposure, and to describe the use of workplace control measures designed to decrease those exposures. The analysis excluded PAH exposure from diesel engine exhaust and environmental tobacco smoke, as these exposures were covered separately in the study, the diesel analysis having already been published(Peters, Carey, et al. 2015).

METHODS

The analysis presented in this report used data from the Australian Workplace Exposures Study (AWES) (Carey et al. 2014). The methods are described in detail elsewhere (Carey et al. 2014; Driscoll et al. 2015) and are summarised here. The AWES was a nationwide telephone survey which investigated the current prevalence and exposure circumstances of work-related exposure to 38 known or suspected carcinogens, including PAHs, among Australian workers aged 18 to 65 years. Using the web-based tool OccIDEAS (Fritschi et al. 2009), semi-quantitative information was collected about exposures in the current job held by the respondent. Questions were addressed primarily at tasks undertaken rather than self-reported exposures. The data and 2011 Census data (Australian Bureau of Statistics 2011) were used to estimate the number of Australian workers currently exposed to PAHs in the course of their work, stratified by gender and conducted separately by occupational group. 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).

RESULTS

Of the 4,993 respondents with complete data, 297 (5.9%) were assessed as having 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. 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 of the exposed respondents worked as managers (mainly farmers), with another 23% working as technicians or trades workers and 15% as community and personal service workers. Occupations with the highest proportion of respondents exposed were community and personal services workers (11%), managers (10%), technicians and trades workers (10%), labourers (9%) and machinery operators and (7%). The occupations with the highest prevalence of exposure were similar when men alone were considered, although the proportions exposed in each occupation were generally higher for males (Table 1). Specific occupation groups with considerable numbers of exposed workers were farmers, health workers, fire fighters, chefs and metal workers (Table 2).

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Agriculture was the most common industry of employment of exposed respondents (40%), with construction (14%) and health care and social assistance (13%) the next highest-represented industries. In the agricultural industry about half the workers were exposed (51%). Other industries with high proportions of persons exposed were public administration and safety (mainly fire fighters) (33%), accommodation and food services (16%), mining (10%) and health care and social assistance (9%). The industries with the highest prevalence of exposure were similar when men alone were considered and the proportions exposed in industry were similar or higher for males (Table 3).

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About 570,000 Australian workers, or 5.7% of the workforce, were estimated to probably be exposed to PAHs when undertaking relatively common activities at work. The exposure occurs predominantly in men. Approximately 470,000 men (8.8% of the male workforce) and approximately 100,000 women (2.2% of the female workforce) were estimated to be exposed.

Circumstances of exposure

The assessed PAH exposure occurred in a variety of circumstances. The main exposure circumstances were exposure to smoke through burning (n=92: 31%), fighting fires (n=21: 7%) or through maintaining mowers or other equipment (an exposure mainly identified in farmers) (n=75: 21%). Other common exposure circumstances were cleaning up ash after a fire (n=37: 13%), health workers exposed to diathermy smoke (smoke arising from cauterisation during surgery) (n=37: 13%), cooking (n=28: 9%), and welding surfaces with a coating such as paint (n=17: 6%) (Table 4).

The use of ventilation systems and respiratory protection equipment

There was little or no information available 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.

Taking into account all fire-fighting activities (front-line fire-fighting, fire overhaul and clean-up, or back-burning), nine fire fighters (43%) always or usually used breathing apparatus while undertaking fire fighting activities and 12 fire fighters (57%) never or only sometimes used breathing apparatus, with particularly low use of breathing apparatus during back-burning. 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

This study showed that PAHs is a common occupational exposure, with approximately 5.7% of the Australian workforce (572,000 people) estimated to be exposed to PAHs when performing any of a range of activities at work. Particularly common activities that entailed probable exposure to PAHs were exposure to smoke from burning or fighting fires and exposure to engine exhaust fumes when doing maintenance work on mowers or other equipment.

Many of the industries with higher exposure prevalence in the current study (agriculture, forestry and fishing; public administration and safety; and accommodation and food services; and mining) were similar to those found in the CAREX study for Western Europe in the early 1990s (electricity, gas and water; manufacturing; construction; and mining) (Finnish Institute of Occupational Health 1998) and the more recent CAREX Canada study (restaurants and other cooking establishments; petrol stations; and public administration) (CAREX Canada 2014). The exposure prevalence of about 6% to 7% seen in this study was much higher than the 0.7% exposure prevalence estimation determined by CAREX and the estimate of about 2% in 2014 by CAREX Canada. The most likely reasons for these differences are considered in more detail elsewhere (Driscoll et al. 2015), but they are probably related to differences in the methods used in the studies and in particular lower levels of exposure or a lower required probability of exposure than those used in the other studies. The level of exposure in the AWES project was based on exposure whilst undertaking the relevant task(s). The AWES data does provide some qualitative information on exposure level, but frequency of activity was not taken into account in these determinations, and duration only to a limited extent. Therefore AWES data address the level of exposure during an activity rather than attempting to provide an assessment of full time-weighted average exposures. The methods used in the AWES project suggest the study is likely to provide a nationally representative estimate of exposure.

There was not a lot of information on the use of control measures for many of the PAH-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 not used effectively by more than half the respondents, mainly because it was used for less than half the time respondents were exposed. About 40% of fire fighters reported always or usually using breathing apparatus while working, meaning that about 60% were commonly not protected appropriately for some of their tasks.

The methodological limitations and strengths of the study are also considered in more detail elsewhere (Driscoll et al. 2015) and included non-response, self-report data, limitations on the amount of detailed data and the qualitative nature of the assessments. Strengths of the approach include that it was task-focused and provided nationally representative information. The main implications of the work are that a considerable number of workers are exposed to PAH in the course of their work and that the use of controls by potentially exposed workers was generally poor. Where information on the use of controls was collected, many respondents reported not using respiratory protective equipment or reported not using any controls to prevent exposures. In particular, fire fighters should be encouraged to always use appropriate breathing apparatus when fighting fires and working on fire overhaul and clean up.

CONCLUSIONS

This study provides the first population-based estimate of occupational exposure to PAHs in Australia and is one of few internationally to provide an estimate based on the nature and extent of reported tasks rather than self-reported exposure to specific agents. PAHs exposure occurs in a range of occupations and industries and a variety of different occupational circumstances. In particular, we found that workers in agriculture, forestry and firefighting were most at risk of exposure. This information, and information on the circumstances of exposure, including the use of personal protective equipment, can be used to support decisions on appropriate priorities for intervention and control of occupational exposures, and estimates of burden of cancer arising from occupational exposure to PAHs.

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Table 1: Occupation of all probable PAHs-exposed respondents (number and per cent) and proportion of respondents in each occupation who were exposed to PAHs (males, females and persons – per cent) - by exposure level (per cent)

	Probably exposed respondents		Proportion probably exposed[a]			Exposure level			
Occupation	**Number[b]**	**%[c]**	**Males %[d]**	**Females %[e]**	**Persons %[f]**	**High %[g]**	**Medium %[g]**	**Low %[g]**	**Total**
Managers	99	33.3	15.4	4.4	10.4	66.7	29.3	4.0	100
Professionals	38	12.8	3.4	1.6	2.3	7.9	7.9	84.2	100
Technicians and trades workers	68	22.9	9.9	9.6	9.9	20.6	7.4	72.1	100
Community and personal service workers	43	14.5	26.4	4.1	11.1	27.9	39.5	32.6	100
Machinery operators and drivers	17	5.7	7.1	-	6.5	47.1	35.3	17.6	100
Labourers	30	10.1	10.2	4.5	8.5	46.7	30.0	23.3	100
Uncertain[h]	2	0.7	-	-	-	50.0	-	50.0	100
Total	**297**	**100.0**	**8.6**	**2.6**	**5.9**	**39.7**	**23.2**	**37.0**	**100**

a: Percentages not provided if there were less than three subjects in the category.

b: Number of respondents who had probable exposure to PAHs.

c: Proportion of exposed respondents who were in each occupation group.

d: Proportion of all male respondents in each occupation group who had probable exposure to PAHs.

e: Proportion of all female respondents in each occupation group who had probable exposure to PAHs.

f: Proportion of all respondents in each occupation group who had probable exposure to PAHs.

g: Percentage of persons exposed in the given exposure circumstance who were exposed at this exposure level.

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

Table 2: Exposure level and main activities resulting in exposure to PAHs – by specific occupation (per cent)

Occupation[a]	N	Exposure level				Main activities resulting in exposure
		High %[b]	Medium %[b]	Low %[b]	Total %	
Farmer	106	66.0	34.0	0.0	100	Maintaining mower or other equipment; burning waste in the open or in an incinerator
Health worker	35	0.0	0.0	100.0	100	Diathermy
Chef	24	0.0	0.0	100.0	100	Deep fry; BBQ; use wok
Fire fighter	20	60.0	40.0	0.0	100	Fighting fires and fire overhaul
Metal worker	17	0.0	0.0	100.0	100	Welding material with surface coating
Gardener	10	100.0	0.0	0.0	100	Burning waste in the open
Carpenter	9	0.0	66.7	33.3	100	Applying or using creosote
Police officer	9	0.0	88.9	11.1	100	Fighting fires; working on firing range

a: This table does not include all exposed respondents. Respondents could have been exposed through more than one activity.

b: Percentage of persons exposed in the given exposure circumstance who were exposed at this exposure level.

Table 3: Industry of all probable PAHs-exposed respondents (number and per cent) and proportion of respondents in each industry who were exposed to PAHs (males, females and persons – per cent) - by exposure level (per cent)

	Probably exposed respondents		Proportion probably exposed[a]			Exposure level			
Industry	**Number[b]**	**%[c]**	**Male %[d]**	**Female %[e]**	**Persons %[f]**	**High %[g]**	**Medium %[g]**	**Low %[g]**	**Total**
Agriculture, forestry and fishing	120	40.4	56.8	36.4	51.9	67.5	32.5	-	100
Mining	12	4.0	10.7	10.0	10.6	66.7	8.3	25.0	100
Manufacturing	11	3.7	7.8	0.0	7.0	27.3	18.2	25.0	100
Construction	40	13.5	7.5	0.0	7.2	22.5	22.5	55.0	100
Accommodation and food services	25	8.4	17.6	14.1	15.7	-	-	100.0	100
Transport, postal and warehousing	4	1.3	1.7	0.0	1.5	50.0	25.0	25.0	100
Professional, scientific and technical services	12	4.0	7.8	3.7	6.1	16.7	16.7	66.7	100
Public administration and safety	28	9.4	49.1	11.8	40.0	28.6	42.9	28.6	100
Health care and social assistance	38	12.8	18.7	6.1	9.4	5.3	7.9	86.8	100
Other[h]	7	2.4	-	-	-	42.9	-	57.1	100
Total	**297**	**100.0**	**8.6**	**2.6**	**5.9**	**39.7**	**23.2**	**37.0**	**100**

a: Percentages not provided if there were less than three subjects in the category.

b: Number of respondents who had probable exposure to PAHs.

c: Proportion of exposed respondents who were in each industry group.

d: Proportion of all male respondents in each industry group who had probable exposure to PAHs.

e: Proportion of all female respondents in each industry group who had probable exposure to PAHs.

f: Proportion of all respondents in each industry group who had probable exposure to PAHs.

g: Percentage of persons exposed in the given exposure circumstance who were exposed at this exposure level.

h: There was at least one person from of the trade (wholesale and retail) 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. Four persons had uncertain industry.

Table 4: Main circumstances resulting in probable exposure to PAHs

Exposure circumstance[a]	Exposed persons	Exposure level				Exposed persons
		High	Medium	Low	Total	
	N	%[b]	%[b]	%[b]	%	%[c]
Burning waste	92	84.8	15.2	0.0	100	31.0
Repairing motors	75	0.0	100.0	0.0	100	25.3
Cleaning out ash	37	97.3	2.7	0.0	100	12.5
Health workers with diathermy	37	0.0	0.0	100.0	100	12.5
Cooking	28	0.0	0.0	100.0	100	9.4
Fighting fires and fire overhaul	21	57.1	42.9	0.0	100	7.1
Welding material with a coating	17	0.0	0.0	100.0	100	5.7
Firing range	12	0.0	0.0	100.0	100	4.0
Using asphalt or tar	9	11.1	44.4	44.4	100	3.0
Working with creosote-treated wood	9	0.0	33.3	66.7	100	3.0
Miners with ammonium nitrate fuel oil	6	100.0	0.0	0.0	100	2.0

a: This table does not include all exposed respondents. Respondents could have been exposed through more than one activity.

b: Percentage of persons exposed in the given exposure circumstance who were exposed at this exposure level..

c: Percentage of all exposed persons included in the study who were exposed in the given exposure circumstance.