The Australian Work Exposures Study: Occupational exposure to lead and lead compounds

Timothy R Driscoll[1], Renee N Carey[2], Susan Peters[3], Deborah C Glass[4], Geza Benke[4], Alison Reid[2], Lin Fritschi[2]

1) School of Public Health, University of Sydney, Sydney, Australia
2) School of Public Health, Curtin University, Perth, Australia
3) Occupational Respiratory Epidemiology, School of Population Health, University of Western Australia, Perth, Australia
4) Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia.

**Author to whom correspondence should be addressed:*
Tim Driscoll
School of Public Health
Edward Ford Building (A27)
University of Sydney NSW 2006
Australia
Email: tim.driscoll@sydney.edu.au
Tel: +61-2-93514372

ABSTRACT

Introduction

The aims of this study were to produce a population-based estimate of the prevalence of work-related exposure to lead and its compounds, to identify the main circumstances of exposures, and to collect information on the use of workplace control measures designed to decrease those exposures.

Methods

Data came from the Australian Workplace Exposures Study, a nationwide telephone survey which investigated the current prevalence and circumstances of work-related exposure to 38 known or suspected carcinogens, including lead, 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

307 (6.1%) of the 4,993 included respondents were identified as probably being exposed to lead in the course of their work. Of these, almost all (96%) were male; about half worked in trades and technician-related occupations, and about half worked in the construction industry. The main tasks associated with probable exposures were, in decreasing order: soldering; sanding and burning off paint while painting old houses, ships or bridges; plumbing work; cleaning up or sifting through the remains of a fire; radiator repair work; machining metals or alloys containing lead; mining; welding leaded steel; and working at or using indoor firing ranges. Where information on control measures was available, inconsistent use was reported. Applied to the Australian working population, approximately 6.3% (95% confidence interval (CI) = 5.6 – 7.0) of all workers (i.e. 631,000, 95% CI 566,000 – 704,000 workers) were estimated to have probable occupational exposure to lead.

Conclusion

Lead remains an important exposure in many different occupational circumstances in Australia and probably other developed countries. This information can be used to support decisions on priorities for intervention and control of occupational exposure to lead, and estimates of burden of cancer arising from occupational exposure to lead.

Keywords: cross-sectional study; population prevalence; workers

Word count: 3,594

INTRODUCTION

Lead has been an exposure of concern in the occupational setting for centuries. Inorganic lead compounds are classified by the International Agency for Research on Cancer (IARC) as a probable human carcinogen (Group 2A) (International Agency for Research on Cancer 2006). Other organisations have classified lead similarly to IARC (Committee on Potential Health Risks from Recurrent Lead Exposure of DOD Firing-Range Personnel et al. 2012; National Toxicology Program 2011). Lead exposure at work has been implicated as a risk factor for lung, stomach, kidney and brain cancer, as well as having significant non-malignant adverse effects on neurological, renal, cerebrovascular, reproductive and developmental health (Bellinger 2011; Gidlow 2004; National Toxicology Program 2011; Steenland, Selevan, and Landrigan 1992; Winder and Lewis 1991).

Lead and lead compounds, collectively referred to throughout this report as 'lead', are used in many occupational contexts. Lead is found in organic and inorganic forms, with leaded fuels previously the most common source of exposure to organic lead. Exposure to organic lead may therefore occur in jobs which involve work in traffic, gasoline stations and garages. However, these exposure circumstances are less relevant in many developed countries because of the widespread use of unleaded petrol. In Australia, lead was phased out of petrol in 2002. In the occupational environment, most forms of lead are inorganic. IARC identified the main industries in which work-related exposure to lead occurs as "*lead smelting and refining industries, battery manufacturing plants, steel welding or cutting operations, construction, painting and printing industries, firing ranges, vehicle radiator-repair shops and other industries requiring flame soldering of lead solder, and gasoline stations and garages*" (International Agency for Research on Cancer 2006). This means that workers in a number of industries might be exposed to lead from typical work-related activities which generate lead-containing dusts or fumes. In terms of occupations, IARC separated the relevant occupations into those where workers had on-going exposure (i.e. exposure as a common part of their job activities), those who had a moderate frequency of exposure, and those who were exposed but at a low frequency. The identified occupations were:

- on-going exposure: battery-production workers, battery-recycling workers, foundry workers, lead chemical workers, lead smelter and refinery workers, leaded-glass workers, pigment workers, vehicle radiator-repair workers and traffic controllers;

- moderate frequency of exposure: firing-range instructors, house renovators, lead miners, newspaper printers, plastics workers, rubber workers, jewellery workers, ceramics workers and steel welders and cutters; and
- low frequency of exposure: automobile-repair workers, cable-production workers, construction workers, demolition workers, firing-range participants, flame solder workers, plumbers and pipefitters, pottery-glaze producers, ship-repair workers and stained-glass producers.

The level and frequency of exposure varies considerably across these occupations, from regular and potentially significant, to occasional and likely to be only at low level. While it is known that some of these activities are undertaken in Australia, there is little information about the nature of general workplace exposures in Australia and limited data on exposures at a population level elsewhere (CAREX Canada 2014; Finnish Institute of Occupational Health 1998; Peters et al. 2015). Information on this should help inform approaches to control such exposures.

The aims of this analysis were to produce a population-based estimate of the prevalence of work-related exposure to lead in Australia, to identify the main circumstances of exposures, and to describe the use of workplace control measures designed to decrease those exposures.

METHODS

The analysis presented in this report uses data from the Australian Workplace Exposures Study (AWES) (Carey et al. 2014). The AWES project was a nationwide telephone survey which investigated the current prevalence of work-related exposure to 38 known or suspected carcinogens, including lead, among Australian workers. Ethics approval was obtained from the University of Western Australia's Human Research Ethics Committee.

The data collection for AWES has been described in more detail previously (Carey et al. 2014). In brief, Australian residents aged between 18 and 65 years in current paid employment were eligible to participate. Those with insufficient English language ability and those who were too ill to participate were ineligible. Data from 5,023 respondents were collected by trained interviewers using computer-assisted telephone interviews after verbal informed consent was provided. Useable information was available from 4,993 respondents, who formed the final study population. Data collection took place from late 2011 to mid-2012.

Occupational information was obtained about the current job held by the respondent. The interview was considered complete if the respondent's occupation fell into one of the thirteen pre-determined job categories not considered exposed to any of the 38 carcinogens (such as white collar professionals). A total of 2,532 respondents were categorised as unexposed at this point and only minimal information was collected from these persons. Otherwise, the interviewer obtained more information (including job title, main tasks carried out in the job, industry of employment, hours worked per week, and weeks worked per year) and subsequently assigned one of 57 job-specific modules (JSMs).

Each JSM comprised questions about both the general working environment and specific tasks. These questions had been developed based on published literature and the experience of the occupational hygienists in the team. Where appropriate, information was collected about the frequency of tasks and control measures. All questions were tailored to Australian industry and occupational conditions. Where a specific JSM could not be assigned, a generic JSM was used. The JSMs were part of OccIDEAS, a web-based tool which manages interviews and the exposure assessment process (Fritschi et al. 2009). Each full interview took 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).

OccIDEAS was used to provide assessments of the probability of occupational exposure to lead, using the categories “no”, “possible”, or “probable” exposure using in-built algorithms. Where a probable exposure was assigned, exposure level was assessed as low, medium, high, or unknown. A low level of exposure was defined as ‘present but not likely to require further control measures’; high exposure as ‘control measures are likely to be needed’; and medium as a level between these values (Fritschi et al. 2012). These rules took into account the use of exposure control measures where this information was available.

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 lead were included in the main analysis. The overall prevalence of lead-exposed workers was estimated by dividing the number of exposed respondents by the total number of AWES respondents. The proportion of respondents within a given occupation or industry who were exposed to lead was estimated by dividing the number of exposed respondents in a given occupation or industry by the number of AWES respondents within that occupation or industry. Assessments were extrapolated with reference to the 2011 Census (Australian Bureau of Statistics 2011) to calculate an estimate of the number of Australian workers 18 years and over currently exposed to lead 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.

RESULTS

Three hundred and seven (6.1%) of the 4,993 respondents included in the analysis were assessed as having probable exposure to lead in their current job. Another 126 respondents had possible exposure (these are not considered further in this analysis). Overall, 10.7% of males and 0.5% of females in the study were assessed as probably being exposed to lead. Two hundred and ninety-five (96.1%) exposed respondents were male and the mean age was 44.5 years (standard deviation = 11.1 years). The level of exposure was deemed to be high for 133 (43.3%), medium for 109 (35.5%) and low for 65 (21.2%) of those exposed. Just over half (54%) of the exposed respondents worked in trades and technical occupations, with 13% working as labourers and 12% working as managers (mainly farmers). Occupations with the highest proportion of workers exposed were technicians and trades workers (24%) and labourers (11%). Male community and personal service workers (mainly fire fighters and police officers) also had a high proportion of exposed persons (23%) (Table 1). Specific occupation groups with considerable numbers of exposed workers were vehicle workers, plumbers, metal workers, electrical workers, farmers, fire fighters and painters (Table 2).

INSERT TABLE 1 ABOUT HERE
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Construction was the industry of employment of almost half the exposed respondents (49%), with agriculture, forestry and fishing (11%) and mining (7%) the next highest-represented industries. Industries with the highest proportion of persons exposed were construction (27%), public administration and safety (26%; all were fire fighters), mining (20%) and agriculture, forestry and fishing (15%). The industries with the highest prevalence of exposure were similar for men only (Table 3).

INSERT TABLE 3 ABOUT HERE

Using 2011 Census data (Australian Bureau of Statistics 2011) and the estimated proportions of workers exposed in each major occupation and industry group, stratified by gender, the numbers of exposed workers in each major occupation and industry group and overall at national level were estimated. These estimates suggest about 631 000 Australian workers, or 6.3% of the workforce, are probably exposed to lead when undertaking relatively common activities at work. The estimated exposure occurs predominantly in men. Approximately 603 000 men or 11.2% of the male workforce and approximately 28 000 women or 0.6% of the female workforce are estimated to be exposed (see Supplementary Table S1 in online edition).

INSERT TABLE 3 ABOUT HERE

Circumstances of exposure

The assessed lead exposure occurred in a variety of circumstances. These were, in decreasing order of frequency, soldering; sanding or burning off paint in preparation for painting; general plumbing; cleaning up or sifting through the remains of a fire; handling lead flashing; repairing engine radiators; using or cleaning an indoor firing range; machining brass, bronze, lead-plated metal or leaded alloys; mining lead ores or other ores containing lead; and welding leaded steel (Table 4).

INSERT TABLE 4 ABOUT HERE

The main circumstances resulting in assessed high, medium or low exposures were:

High:

- soldering in enclosed areas or mainly indoors without appropriate use of a hood or helmet;
- sanding old houses, ships or bridges using a power sander or burning off paint without use of a suitable respirator;
- repairing engine radiators;
- welding leaded steel in confined spaces or mainly indoors without appropriate use of a hood or helmet; and
- mining lead ores or other ores containing lead.

Medium:

- soldering not in enclosed areas and with common (more than 50% of the time) use of either a hood or helmet or commonly working outdoors;
- sanding old houses, ships or bridges – by hand or commonly using a suitable respirator when burning off paint;
- machining brass, bronze, lead-plated metal or leaded alloys without use of appropriate ventilation;
- instructing or firing guns in an indoor firing range; and

- cleaning up or sifting through the remains of a fire without commonly using appropriate breathing apparatus.

Low:

- general plumbing work;
- handling lead flashing;
- cleaning up or sifting through the remains of a fire commonly using appropriate breathing apparatus or fighting residential fires;
- sanding old houses, ships or bridges – by hand and commonly using a suitable respirator; and
- machining brass, bronze, lead-plated metal or leaded alloys with use of appropriate ventilation.

Note that electricians who were soldering were considered to have only possible exposure to lead and so were not included in the analysis presented here.

The use of control measures in circumstances that entailed potential exposure to lead was inconsistent. The main control measures reported related to decreasing the chance of inhalation. These measures included the use of soldering or welding hoods, face masks or half-face respirators, and as well as working outdoors or in ventilated areas. Ventilation was typically either by dilution or local exhaust ventilation.

DISCUSSION

This study showed that lead is a common occupational exposure, with approximately 6.3% of the Australian workforce likely to be exposed, virtually all in the form of inorganic lead. Soldering and some painting tasks were particularly common activities that entailed probable exposure.

The industries and tasks identified as having high prevalence were similar in the AWES project to many of those identified in other studies. This observation is not surprising because the exposure classification rules built into the AWES database were based on much of the same published literature that other studies would have used for their assessments. In this study, the industries with the highest prevalence of exposure were construction; agriculture, forestry and fishing; mining; transport, postal and warehousing; and public administration and safety. The prevalence of work-related exposure to inorganic lead in CAREX was highest in the electricity, gas and water; manufacturing; construction; mining; and transport and storage industries (Finnish Institute of Occupational Health 1998; Kauppinen et al. 2000). The CAREX Canada database identified the industries with the highest prevalence of exposure to lead as public administration, building equipment and contractors, automotive repair and maintenance, and commercial and industrial machinery repair and maintenance. The main tasks identified in this study were soldering; sanding and burning off paint while painting; and general plumbing. In Canada, the main occupational exposures (in terms of number of people exposed) were welders, police officers and, for men, car mechanics, plumbers and pipefitters (CAREX Canada 2014; Peters et al. 2015).

The exposure prevalence of 6% seen in this study was much higher than the 1.1% estimated by the CAREX study for Western Europe in the early 1990s (Finnish Institute of Occupational Health 1998) and the more recent CAREX Canada estimate of about 2% for 2014 (CAREX Canada 2014). The UK cancer burden study by Rushton and co-workers (Brown et al. 2012; Van Tongeren et al. 2012) estimated an overall lead exposure prevalence of 4.2% for men and 2.0% for women. This was the proportion of the working cohort that was ‘ever’ exposed in the 10 to 50 year relevant exposure period. The point prevalence, which is essentially what AWES estimates, would be considerably less. Exposure prevalence was also much higher in the current study than in CAREX for specific industries. The contrast of the higher exposure prevalence estimate in this study compared with the CAREX study is emphasised because 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.

Some of the differences in the overall prevalence estimates between the studies may reflect the different industry profiles in the countries in which the studies were based (for example, Australia has a higher proportion of persons employed in agriculture and mining than the UK, but similar to Canada), but the main cause of the differences is likely to be differences in the methods used in the studies. The AWES project was the only study that surveyed workers about the tasks they actually performed at work and took into account the use or non-use of control measures. CAREX and CAREX Canada estimates were based on workplace measures and on expert opinion. The UK Burden study used a similar approach, and relied heavily on CAREX estimates, but probably had better local exposure information at a broad industry level. The definition of exposure in the four studies also appears to have been different but it is difficult to make a direct comparison. The higher exposure prevalence estimated for the Australian working population by AWES suggests estimates might be based on 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 and was not intended to necessarily relate to an assessment of the time-weighted average exposure of that person. That was probably also the case for the CAREX and UK studies. Finally, the estimates in some specific industries may be a little high because persons with office-based jobs provided only basic information that was insufficient to allocate them to a particular industry, meaning the denominator used for some industries may have been underestimated even though the all-industry denominator was correct (e.g. an unexposed office worker actually employed in the construction industry would have been included in the study but would not have had enough information collected to allow them to be allocated to the construction industry when calculating the proportion of study subjects within a particular industry group who were exposed). Countering that is that the analysis did not include people assessed as having possible exposures. Relevant examples included people sanding unknown material, electricians soldering, industrial manufacturing of metal products, applying ceramic glazes, police involved in dismantling clandestine drug labs and teaching metal work. Overall, the methods used in the AWES project suggest the study is likely to provide a nationally representative estimate of exposure.

The CAREX, CAREX Canada, UK and AWES data sources all provide information on exposure prevalence rather than quantitative information on exposure. The AWES data does provide some qualitative information on exposure level, but as mentioned this addresses the level of exposure during an activity rather than attempting to provide an assessment of full time-weighted average exposures. Frequency of activity was not taken into account in these determinations, and duration only to a limited extent. There are databases which provide qualitative exposure information for some carcinogenic exposures, such as the COLCHIC database in France (Vincent and Jeandel 2001) and the Occupational Safety and Health Administration's IMIS database in the United States (Stewart and Rice 1990). The advantages and disadvantages have been considered by a number of authors, the benefits including the provision of information that potentially allows accurate quantitative risk assessment, and the concerns including the lack of representativeness of the included measurements across workers, the relevant company and the relevant industry; inaccuracies in the measurements; and lack of required information about the circumstances and methods of collection (Goldman et al. 1992; LaMontagne et al. 2002; Lavoué, Gerin, and Vincent 2011; Lavoué, Vincent, and Gerin 2008; Olsen, Laursen, and Vinzents 1991).

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. Specific questions on the provision of washing facilities or wipe-downs of dusty areas which might prevent ingestion of lead dust through hand-mouth transfers were not included. Soldering was found to be the most common form of exposure to lead and the use of appropriate exposure control measures, such as wearing an air-supplied helmet, was uncommon (46%). This is a particular concern because inhalation of lead fume can be a significant source of lead exposure(National Toxicology Program 2011). We categorised such exposure as high or medium based on the described tasks, but whether the level of lead exposure in soldering in different circumstances should be classified as high, medium or low is open to debate.

Data were collected through a telephone survey, with attendant time restraints in terms of maintaining the respondent's cooperation, which limited the breadth and depth of data that could be collected. 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 be expected 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 workers undertaking tasks that would usually be viewed as having a high risk of significant lead exposure such as recycling (or manufacturing) lead-acid batteries, but which do not comprise a significant proportion of the workforce, were not found in the study sample. As noted previously, exposure assessments were qualitative. They referred to exposure levels relevant to suspected carcinogenic outcomes (i.e. they do not necessarily correlate to airborne exposure standards or to blood lead removal levels); and to the level of exposure whilst undertaking the relevant task (i.e. they are not a direct 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 was collected on the use of controls was necessarily somewhat limited due to limitations in the number of questions that could be asked. Non-response is also an issue for any survey, raising the possibility that those who did participate in the current study had a different prevalence of exposure and different approach to the use of exposure control measures than those who did not participate. Since there is no employment information available on non-participants it is not possible to assess this potential problem in detail. However, the initial study sample was stratified to reflect the approximate distribution of the Australian workforce by state and territory, and the respondents were similar to the general population in terms of state of residence, gender, education level, socioeconomic status and remoteness. However, compared to the general Australian population respondents were older, less likely to have been born in outside Australia, and less likely to speak a language other than English at home.

In general, some of the health risks posed by exposures to lead, the tasks that might result in such exposures and the methods of preventing exposure should be well understood by employers and workers (Australian Institute of Occupational Hygienists 2009). However, the use of control measures by workers in the AWES sample was generally poor. There is an opportunity to prevent work-related exposures to lead, and reduce the potential for work-related cancer cases, through efforts to increase the number of workplaces that eliminate the use of lead where possible or consistently use high order controls and good work practices to eliminate or reduce exposures to lead when relatively common activities are carried out. Examples include installing soldering booths or local exhaust ventilation if soldering activities are fairly common in the workplace. Where this is not practicable, an option is to provide respiratory protective equipment and ensure that it is used when workers are soldering. Another important approach is ensuring that power sanders are fitted with dust collectors and that workers wear appropriate respiratory protective equipment when they sand old structures or burn off paint prior to painting or repairing them.

Quantitative measures of lead exposure in the workplace could validate the data collected in AWES and help better understand the absolute levels of exposure to lead. Blood lead surveys are considered the most appropriate form of bio-monitoring in the lead industries, but such surveys are seldom undertaken in industries where the blood lead levels are considered low, or which were not defined as lead industries in past legislation(Gwini et al. 2012). More detailed information on the use of control measures would be particularly useful in those work situations highlighted in this study where probable lead exposures were assessed as being at a high level, as it would be helpful to understand why appropriate control measures are not used where and when they should be. Such information would allow interventions and prioritisation of action to be based on sound evidence.

CONCLUSIONS

This study provides the first population-based estimate of probable occupational exposure to lead in Australia and is one of few internationally to provide an estimate based on reported tasks rather than self-reported exposure to specific agents. Lead exposure is common in a range of occupations and industries and a variety of different occupational circumstances and is not confined to the traditional industries where lead exposure is probably most intense. This information, and information on the circumstances of exposure, can be used to support decisions on priorities for intervention and control of occupational exposures, and estimates of burden of cancer arising from occupational exposure to lead.

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

	Probably exposed respondents		Proportion probably exposed		Exposure level			
			Male	Persons	High	Medium	Low	Total
Occupation	Number[a]	%[b]	%[c]	%[d]	%	%	%	%
Managers	38	12.4	7.1	4.0	34.2	47.4	18.4	100
Professionals	17	5.5	2.2	1.0	23.5	17.6	58.8	100
Technicians and trades workers	165	53.7	26.7	23.9	57.0	31.5	11.5	100
Community and personal service workers	30	9.8	23.1	7.8	6.7	36.7	56.7	100
Machinery operators and drivers	12	3.9	5.0	4.6	66.7	25.0	8.3	100
Labourers	40	13.0	14.8	11.3	27.5	45.0	27.5	100
Other[e]	5	1.6	-	-	20.0	80.0	-	100
Total	**307**	**100.0**	**10.7**	**6.1**	**43.3**	**35.5**	**21.2**	**100**

a: Number of respondents who had probable exposure to lead.

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

c: Proportion of all male respondents in each occupation group who had probable exposure to lead (female results not shown as the number of exposed respondents was too low).

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

e: There was at least one person from the clerical and administrative workers and sales categories and one person with uncertain occupation. Numbers and percentages for these are not shown because there were less than three persons in each category.

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

Occupation[a]	N	Exposure level				Main activities resulting in exposure
		High %	Medium %	Low %	Total %	
Vehicle worker	47	80.9	17.0	2.1	100	Soldering, grinding welds, radiator repair
Plumber	37	32.4	45.9	21.6	100	Soldering, plumbing, lead flashing, grinding welds
Metal worker	32	56.3	34.4	9.4	100	Soldering, grinding welds
Fire fighter	21	-	19.0	81.0	100	Fire overhaul
Electrical worker	28	57.1	35.7	7.1	100	Soldering, painting old houses
Farmer	28	42.9	57.1	0.0	100	Soldering, grinding welds, painting old houses
Painter	19	63.2	36.8	0.0	100	Painting old houses
Engineer	11	18.2	36.4	45.5	100	Plumbing, soldering

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

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

	Probably exposed respondents		Proportion probably exposed		Exposure level			
			Male	Persons	High	Medium	Low	Total
Industry	**Number[a]**	**%[b]**	**%[c]**	**%[d]**	**%**	**%**	**%**	**%**
Agriculture, forestry and fishing	35	11.4	18.2	15.2	40.0	60.0	-	100.0
Mining	22	7.2	19.4	19.5	45.5	40.9	13.6	100.0
Manufacturing	15	4.9	10.6	9.5	60.0	26.7	13.3	100.0
Construction	150	48.9	28.0	27.0	48.0	32.7	19.3	100.0
Trade (wholesale and retail)	5	1.6	7.1	5.7	40.0	40.0	20.0	100.0
Transport, postal and warehousing	20	6.5	8.7	7.5	70.0	25.0	5.0	100.0
Professional, scientific and technical services	14	4.6	10.3	7.1	14.3	35.7	50.0	100.0
Public administration and safety	18	5.9	30.2	25.7	5.6	50.0	44.4	100.0
Education and training	5	1.6	8.9	5.4	20.0	-	80.0	100.0
Health care and social assistance	6	2.0	5.6	1.5	16.7	16.7	66.7	100.0
Other[e]	17	5.5	12.8	8.5	41.2	23.5	35.3	100.0
Total	**307**	**100.0**	**10.7**	**6.1**	**43.3**	**35.5**	**21.2**	**100.0**

a: Number of respondents who had probable exposure to lead.

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

c: Proportion of all male respondents in each industry group who had probable exposure to lead (female results not shown as the number of exposed respondents was too low).

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

e: Industry was not known for six respondents and 11 respondents worked in industries other than those listed in the table—these respondents are classified as 'Other'

Table 4: Main circumstances resulting in probable exposure to lead

Exposure circumstance[a]	Exposed persons	Exposure level				Exposed persons
		High	Medium	Low	Total	
	N	%[b]	%[b]	%[b]	%	%[c]
Soldering	177	53.7	46.3	0.0	100	59.6
Painting preparation	47	40.4	48.9	10.6	100	15.8
Plumbing - general	42	0.0	0.0	100.0	100	14.1
Fire fighting	20	0.0	20.0	80.0	100	6.7
Handling lead flashing	16	0.0	0.0	100.0	100	5.4
Radiator repair	13	100.0	0.0	0.0	100	4.4
Firing range	12	8.3	91.7	0.0	100	4.0
Machining	11	0.0	72.7	27.3	100	3.7
Mining	9	66.7	22.2	11.1	100	3.0
Welding leaded steel	8	75.0	25.0	0.0	100	2.7

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.