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## ORIGINAL ARTICLE

# Estimated prevalence of exposure to occupational carcinogens in Australia (2011–2012)

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## ABSTRACT

**Background and objectives** Although past studies of workplace exposures have contributed greatly to our understanding of carcinogens, significant knowledge gaps still exist with regard to the actual extent of exposure among current workers, with no routinely collected population-based data being available in most countries. This study, the Australian Work Exposures Study (AWES), aimed to investigate the current prevalence of occupational exposure to carcinogens.

**Methods** A random sample of men and women aged between 18 and 65, who were currently in paid employment, were invited to participate in a telephone interview collecting information about their current job and various demographic factors. Interviews were conducted using a web-based application (OccIDEAS). OccIDEAS uses the expert exposure method in which participants are asked about their job tasks and predefined algorithms are used to automatically assign exposures. Responses were obtained from 5023 eligible Australian residents, resulting in an overall response rate of 53%.

**Results** 1879 respondents (37.6%) were assessed as being exposed to at least one occupational carcinogen in their current job. Extrapolation of these figures to the Australian working population suggested 3.6 million (40.3%) current workers could be exposed to carcinogens in their workplace. Exposure prevalence was highest among farmers, drivers, miners and transport workers, as well as men and those residing in regional areas.

**Conclusions** This study demonstrates a practical, web-based approach to collecting population information on occupational exposure to carcinogens and documents the high prevalence of current exposure to occupational carcinogens in the general population.

## INTRODUCTION

Over 165 occupational carcinogens have been identified by the International Agency for Research on Cancer (IARC).<sup>1</sup> In addition, 18 occupations (eg, painter) or exposure circumstances (eg, firefighting) have been associated with an excess risk of cancer. Exposures to these carcinogens contribute significantly to the burden of cancer, with a recent study in the UK estimating that 8.2% of all cancers in men and 2.3% in women were related to occupation.<sup>2</sup> Occupational exposures are of particular concern as, unlike lifestyle exposures such as diet and alcohol, they are encountered involuntarily and are commonly of greater magnitude than exposures in the general environment.<sup>3</sup> Such exposures are

## What this paper adds

- There exist significant knowledge gaps with regard to the extent of occupational exposure to carcinogens among workers in many countries.
- Information regarding the prevalence of occupational exposure is necessary in order to target prevention efforts and understand patterns of exposure, as well as to estimate the burden of occupational cancer arising from these exposure.
- This study provides evidence that the overall prevalence of exposure to occupational carcinogens among Australian workers is of concern.
- Patterns of exposure differ across occupational and demographic groups, with those most at risk of exposure being male workers residing in regional areas.

also more likely to be amenable to risk reduction by implementing controls in the workplace rather than by changing individual behaviour.<sup>4</sup>

Past studies of workplace exposures have contributed greatly to our understanding of carcinogens and cancer aetiology.<sup>5</sup> However, significant knowledge gaps still exist regarding the actual extent of exposure among workers in many countries, including Australia, as well as the trends in exposure over time. National exposure surveillance is not widely carried out in Australia, meaning that routinely collected population-based data concerning the prevalence and extent of exposure are not available.<sup>6</sup> Those studies that have investigated the prevalence of occupational exposure have generally focused on specific exposures (eg, benzene)<sup>7</sup> or particular high-risk industries (eg, aluminium production industry),<sup>8</sup> rather than investigating a range of occupational exposures across the whole working population. This means that the carcinogens encountered by workers in other industries (eg, prevalence of diesel exposure among farmers) and from unstudied carcinogenic agents have likely been underestimated.<sup>9</sup> Additionally, many studies have relied on job title alone as an indicator of exposure, despite the probability of considerable variability in exposure within the same job title or occupation.<sup>10</sup>

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In the USA, national occupational exposure data based on site visits to industrial facilities are available through the National Occupational Exposure Survey<sup>11</sup>; however, these data have not been updated since 1990. In addition, national exposure databases using the CARcinogen EXposure (CAREX) model are available in Canada,<sup>12</sup> Finland<sup>13</sup> and Costa Rica.<sup>14</sup> The extent to which these exposure assessments can be applied to workers in other countries is unclear, particularly where the exposure circumstances are clearly different. For example, estimates of solar ultraviolet radiation exposure obtained from Finland<sup>15</sup> are likely to result in an underestimate of exposure when applied to Australia. In addition, the carcinogenic agents to which workers may feasibly be exposed vary between countries, with differences in, for example, manufacturing processes and legislation concerning the use of certain chemicals.

An alternative, more standardised exposure assessment method that may be used in large-scale, community-based studies is the job exposure matrix (JEM). These matrices assign exposures based on a cross tabulation of job titles and agents, with the measure of exposure being dichotomous (ever vs never exposed) or ordinal (categories of exposure).<sup>16</sup> A quantitative JEM (assigning levels of exposure) has also recently been developed for use in community-based studies,<sup>17, 18</sup> although this may not be applicable to Australia. Further, a limitation of JEMs is that they typically allocate the same assessment to all workers with the same job title,<sup>19</sup> despite the fact that exposures may vary widely between workers.<sup>20</sup>

Large-scale surveys covering the entire working population may therefore be necessary to gain a more complete view of the prevalence of occupational exposures.<sup>21</sup> A number of such surveys have been carried out in countries including the UK,<sup>22</sup> South Korea<sup>23</sup> and New Zealand,<sup>9</sup> as well as the ongoing European Working Conditions Survey which collects data from workers across Europe.<sup>24</sup> These surveys generally use similar methodology: interviewing workers from the general population about their work environment and collecting information about categories of exposure (eg, 'chemical substances', 'smoke/dust') rather than specific agents. In Australia, the National Hazard Exposure Worker Surveillance (NHEWS) survey was carried out in 2008.<sup>25</sup> NHEWS collected data from 4500 Australian workers and found that 39% were exposed to airborne hazards<sup>26</sup> and 37% to chemicals including detergents, organic solvents and disinfectants.<sup>27</sup> However, the survey targeted workers in predetermined priority industries, meaning that these results are not representative of exposures experienced by the general Australian working population.

In addition, the exposure assessments were based on self-report to open-ended questions, and thus the extent to which the results reflect the true prevalence of exposure among those who took part is unknown. While workers can self-report tasks or activities that they commonly undertake with reasonable accuracy, the ability of participants to accurately self-report specific exposures varies with the agent of interest and, more importantly, there is likely to be bias due to rumination by subjects with the disease.<sup>28, 29</sup> They may also be unaware of exposures,<sup>30</sup> and generally have no objective standard against which to judge their own exposures and working conditions.<sup>28, 31</sup>

A more objective method is expert assessment, whereby experts (typically occupational hygienists and physicians) make an assessment based on a review of an individual's job history in combination with the published literature, available exposure measurements, and their own experience and knowledge.<sup>32</sup> Expert assessment is thought to be the most accurate and credible exposure assessment method for large scale studies,<sup>16</sup>

although the process has been described as a 'black box' whereby it can be difficult to determine how an exposure assessment has been arrived at.<sup>32</sup> This may be overcome by the use of an automated expert assessment system which makes the assessment process more transparent and consistent. Moreover, the automated assessment makes it possible to assess a wide range of occupational exposures in the general population in an efficient way.<sup>32</sup>

The current study therefore used an automated expert assessment method (OccIDEAS) to gain a complete view of the current prevalence of exposure to carcinogens among Australian workers, focusing on those agents most relevant to Australian working conditions.

## METHODS

### Study population

The Australian Work Exposures Study (AWES) was a cross-sectional telephone survey investigating the prevalence of current occupational exposure to 38 known or probable carcinogens among Australian workers (table 1). These carcinogens were prioritised according to three criteria: evidence of carcinogenicity (exposures classified as group 1 or 2A) according to IARC; use in occupational circumstances; and evidence of use in Australian industry.<sup>33</sup> Ethics approval for this study was obtained from the (redacted for review) human research ethics committee of the University of Western Australia.

The sample for this study was randomly selected from a list of approximately 6 million Australian households supplied by a commercial survey sampling firm. This list, comprising addresses and telephone numbers, was sourced from various public domain directories, including but not limited to telephone directories. Both landline and mobile phone numbers were included, and the sample was stratified to reflect the approximate distribution of the Australian workforce by state and territory, as reported by the Australian Bureau of Statistics (ABS) Labour Force Survey from March 2011.<sup>34</sup>

Within these households, all Australian residents aged between 18 and 65 and currently in paid employment were eligible to participate. Respondents with insufficient English speaking ability and those who were deaf or too ill to participate were excluded as ineligible. Both male and female workers were included; although as men have been found to be less likely to participate in scientific research than women,<sup>35</sup> a modified interview request was utilised in which men were asked for in six out of seven phone calls. That is, after introducing themselves, the interviewer asked to speak to the person of the specified gender who fit the eligibility criteria (ie, aged between 18 and 65 and currently working). In the case where there was more than one such person, the interviewer asked to speak to the one who had the next birthday.

A total of 19 896 households were telephoned during the course of this study (figure 1). No response was obtained after 10 different call attempts from 2452 households, while 10 485 households were designated ineligible and 1936 refused to participate. Interviews were conducted with 5023 respondents, resulting in a response fraction (completed interviews/eligible and unknown households) of 53% and a cooperation fraction (completed interviews/eligible households) of 72%.

### Data collection

All data were collected by trained interviewers using computer-assisted telephone interviews. Oral informed consent was provided by all respondents. Demographic information, including age, gender, postcode of residence, country of birth, year of

**Table 1** The list of carcinogens as prioritised by Fernandez *et al*<sup>33</sup>

Agent group	Agent
Combustion products (3)	Diesel engine exhaust Environmental tobacco smoke Polycyclic aromatic hydrocarbons (PAHs)*
Inorganic dusts (2)	Asbestos Crystalline silica dust
Organic dusts (2)	Leather dust Wood dust
Metals (7)	Arsenic and inorganic arsenic compounds Beryllium and beryllium compounds Cadmium and cadmium compounds Chromium (VI) compounds Cobalt metal and tungsten carbide Inorganic lead compounds Nickel compounds
Radiation (4)	Artificial ultraviolet radiation (UVA, UVB, UVC) Ionising radiation† Radon-222 and its decay products Solar radiation
Other industrial chemicals (19)	Acid mists, strong inorganic Acrylamide $\alpha$ -chlorinated toluenes‡ Benzene 1,3-butadiene Diethyl sulfate Dimethyl sulfate Epichlorohydrin Ethylene oxide Formaldehyde Glycidol 4,4'-methylenebis (2-chloroaniline) (MOCA) <i>N</i> -nitrosodimethylamine and <i>N</i> -nitrosodiethylamine <i>ortho</i> -Toluidine (2-aminotoluene) Polychlorinated biphenyls (PCBs)§ Styrene-7,8-oxide Tetrachloroethylene (perchloroethylene) Trichloroethylene Vinyl chloride
Non-chemical agents (1)	Shiftwork that involves circadian disruption

\*Includes benzo[a]pyrene, coal-tar pitch, creosotes, cyclopenta[cd]pyrene, dibenz[a,h]pyrene, frying emission from high temperatures, mineral oils (treated or mildly treated), soots.

†Fission products including strontium-90, ionising radiation (all types), neutron radiation, phosphorus-32 as phosphate, radioiodines including iodine-131, internally deposited  $\alpha$ - and  $\beta$ -emitting radionuclides, x- and  $\gamma$ -radiation, and radium-224, radium-226, radium-228, thorium-232 and their decay products.

‡Includes benzal chloride, benzotrifluoride, benzyl chloride and benzoyl chloride.

§Includes 3,4,5,3',4'-pentachlorobiphenyl (PCB-126).

arrival in Australia, language spoken at home and education level was collected. Socioeconomic status and remoteness were determined by applying the ABS Socio-Economic Indexes for Areas Index of Relative Socio-economic Disadvantage<sup>36</sup> and the Australian Standard Geographical Classification Accessibility/Remoteness Index of Australia<sup>37</sup> to the respondent's postcode of residence.

Basic job information was collected to determine whether the respondent's current job corresponded to one of the 13 predetermined categories of jobs which were not exposed to any of the 38 carcinogens. These categories included retail workers, customer service workers, carers, correctional services workers, and psychologists and social workers, as well as those on home duties. The other categories comprised white collar professionals and clerical workers, provided they did not travel or drive as part of their work; takeaway restaurant staff who were not involved in cooking duties; house cleaners, as opposed to

cleaners working in other settings, as these workers were considered unlikely to use harsh chemicals; and early childhood or childcare workers, primary school teachers, and high school teachers not involved in art, science or technical subjects, in contrast to teachers involved in these three subject areas. The 2532 respondents whose job fitted into one of these categories were classified as unexposed and the interview considered complete. For the remaining 2491 respondents, more information regarding their current job was obtained, including job title, main tasks carried out in the job, industry of employment, hours worked per week and weeks worked per year.

Based on this job information, interviewers assigned respondents to one of 57 job specific modules (JSMs). Specific JSMs were completed by 2385 respondents. An appropriate JSM could not be determined for the remaining 106 respondents, and so a generic JSM was utilised in which open-ended questions were used to collect information about the respondent's day-to-day job tasks. All modules were delivered using OccIDEAS, a web-based tool which manages interviews and the exposure assessment process.<sup>32</sup> Each full interview took approximately 15 min.

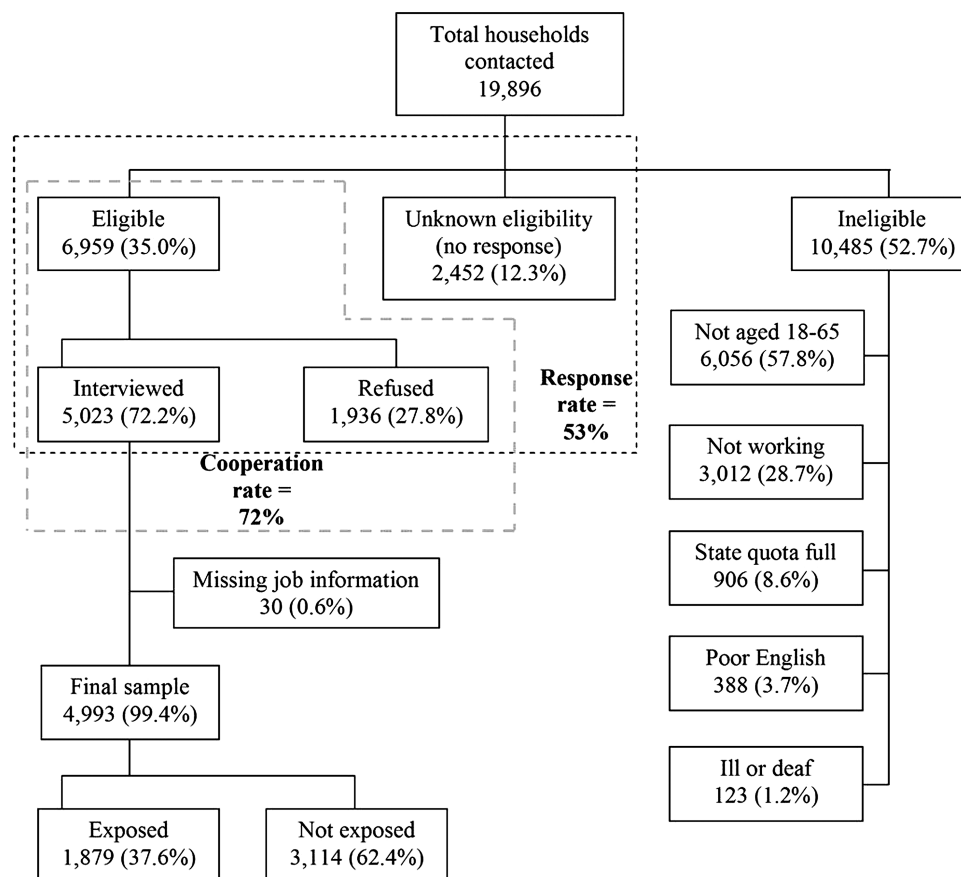
Following the interviews, each of the jobs was coded according to the Australian and New Zealand Standard Classification of Occupations<sup>38</sup> and the International Standard Classification of Occupations 1968.<sup>39</sup> These codes were then categorised into 30 occupational groups, each of which were considered to contain occupations which were relatively homogeneous with regard to exposure to the 38 carcinogens investigated here (see online supplementary table 1). In deciding on these groups, reference was made to the job tasks outlined in the occupation definitions provided by the ABS,<sup>38</sup> and the likely exposures that may result from those tasks. For example, 'funeral workers' were grouped with scientists as their tasks include the preparation of bodies for viewing, which may involve exposure to chemicals such as formaldehyde, other embalming fluids and disinfectants, similar to exposures that may be encountered by medical and science technicians.

## Exposure assessment

The JSMs contained questions about the current completion of job tasks likely to entail exposure to the priority carcinogens, as established with reference to: published literature; reference texts<sup>40-41</sup>; various reports including IARC Monographs,<sup>1</sup> CAREX reports<sup>12</sup> and the National Toxicology Program's 12th Report on Carcinogens<sup>42</sup>; material safety data sheets; and expert knowledge. All JSMs were developed by a team including occupational hygienists and epidemiologists. Modules were only developed for those jobs considered to involve possible exposure to the priority carcinogens and which were reasonably prevalent in Australia.<sup>34</sup>

Each JSM included questions about the general working environment as well as specific tasks completed and, where appropriate, gathered information about the frequency of tasks, task method (eg, using a power sander vs sanding by hand), and any protective measures used (including ventilation, respiratory equipment, gloves, and other protective clothing). Questions focused on what respondents currently do in their job, asking, for example, 'Do you sand wood?' and 'What do you use to thin paints?'. Some task questions were used in more than one module; for example, welding questions appeared in 15 different JSMs including Construction and Mechanic. All questions were tailored to Australian industry and occupation conditions.

The generic JSM collected information about the tasks respondents commonly carry out in their jobs. These JSM



**Figure 1** Response flow chart for the Australian Work Exposures Study (AWES) Sample, Australia, 2011–2012.

answers were then reviewed by two occupational hygienists (DG, SP), who assigned exposures based on the tasks reported and their expert opinion. For all other JSMs, OccIDEAS was used to provide automatic assessments of the probability (either 'no', 'possible' or 'probable') of exposure to each of the 38 carcinogens. Automatic assessments were based on predetermined rules developed on the basis of expert opinion and scientific literature, including, where relevant, exposure measurements. The rules were attached to and triggered by specific answers within the JSM. As an example of a simple rule, if someone answered that they frequently drove along major metropolitan roads, they would be assessed as being exposed to diesel engine exhaust. All automatic assessments were reviewed by project staff and changes to rules were made where appropriate. Any such changes were then applied to all assessments using that rule.

### Statistical analysis

Statistical analyses were conducted using Stata V.12.<sup>43</sup> Prevalence of exposure was defined as the proportion of respondents assessed as being exposed to at least one of the priority carcinogens in their current job, regardless of frequency, duration or level of exposure. A dichotomous measure of exposed or not exposed was used. ORs and 95% CIs were estimated using logistic regression in order to explore which demographic variables were associated with exposure. Both unadjusted and adjusted models were estimated, with occupational group and all other included variables adjusted for in the latter analysis.

These assessments were then extrapolated with reference to the ABS Labour Force Survey<sup>34</sup> to provide an estimate of how many workers in Australia are likely to be exposed to each of

the priority carcinogens. Extrapolations were conducted separately by occupational group and were stratified by gender in order to account for potential exposure differences.

### RESULTS

Of the 5023 completed interviews, 30 had missing job history information and were excluded from analysis. The demographic distribution of the remaining 4993 respondents (2766 male, 2227 female) was compared with the distribution in the Australian working population (aged 18 to 65) using Census 2011 data (see online supplementary table 2).<sup>44</sup> Respondents were similar to the general population in terms of gender, education level, socioeconomic status and remoteness, as well as state of residence. However, respondents were significantly older, more likely to have been born in Australia, and less likely to speak a language other than English at home than the general population. The latter result was expected as it was a requirement of this study that respondents could speak sufficient English to complete the survey.

A total of 1879 respondents (37.6%) were assessed as being probably exposed to at least one of the priority carcinogens. Including possible exposures altered this proportion only slightly ( $n=1912$ , 38.3%); the following analyses were restricted to probable exposures only. Possible exposures are outlined in online supplementary table 3.

After controlling for occupation, respondents assessed as being probably exposed to at least one carcinogen were more likely to be male, to have completed a trade certificate and to reside in regional areas than were unexposed workers (table 2).

**Table 2** ORs and 95% CIs for association between demographic characteristics and assessment of exposure in final sample

Demographic characteristic	Exposed %	Unexposed %	Unadjusted OR	Unadjusted 95% CI	Adjusted OR*	Adjusted 95% CI
Gender						
Male	78.0	41.8	1.00		1.00	
Female	22.0	58.2	0.20	0.18 to 0.23	0.34	0.27 to 0.41
Age						
18–34	17.4	13.7	1.37	1.17 to 1.61	1.13	0.87 to 1.46
35–54	57.6	62.0	1.00		1.00	
55–65	25.0	24.3	1.11	0.97 to 1.28	1.04	0.83 to 1.29
Country of birth						
Australia	80.7	78.9	1.00		1.00	
Other	19.3	21.1	0.89	0.77 to 1.03	1.07	0.85 to 1.35
Language at home						
English	98.2	98.0	1.00		1.00	
Other	1.8	2.0	1.10	0.72 to 1.68	0.92	0.49 to 1.73
Highest education level						
High school or less	40.6	34.9	1.00		1.00	
Trade certificate or diploma	37.9	21.9	1.49	1.29 to 1.71	1.33	1.04 to 1.69
Bachelor degree or higher	21.5	43.2	0.43	0.37 to 0.49	0.84	0.66 to 1.08
State of residence						
New South Wales	31.9	36.1	1.00		1.00	
Victoria	25.6	24.0	1.21	1.04 to 1.40	1.00	0.78 to 1.27
Queensland	19.9	17.1	1.31	1.11 to 1.55	1.08	0.82 to 1.42
Western Australia	12.9	10.4	1.41	1.16 to 1.71	1.05	0.76 to 1.45
South Australia	5.3	6.6	0.90	0.69 to 1.16	0.82	0.54 to 1.23
Australian Capital Territory	1.0	2.9	0.40	0.24 to 0.65	0.89	0.45 to 1.77
Tasmania	2.6	1.6	1.76	1.17 to 2.64	1.12	0.59 to 2.14
Northern Territory	0.8	1.3	0.70	0.38 to 1.28	0.49	0.18 to 1.37
Socioeconomic status						
Highest quintile	21.1	31.1	1.00	1.00		
Fourth	23.1	26.1	1.31	1.11 to 1.54	0.89	0.68 to 1.16
Third	22.8	19.0	1.77	1.49 to 2.10	1.06	0.79 to 1.41
Second	20.9	15.1	2.03	1.70 to 2.43	1.01	0.74 to 1.38
Lowest	12.1	8.7	2.05	1.66 to 2.54	1.30	0.92 to 1.84
Remoteness						
Major city	50.3	66.9	1.00	1.00		
Inner regional	32.4	24.1	1.78	1.56 to 2.03	1.32	1.04 to 1.66
Outer regional	14.6	7.8	2.48	2.05 to 3.00	1.46	1.03 to 2.08
Remote/very remote	2.7	1.2	2.95	1.93 to 4.53	1.88	0.89 to 3.98

\*Adjusted for occupational group and all other variables in model.

No differences were found in terms of country of birth or language most commonly spoken at home.

Significant differences in exposure prevalence were also found by occupational group. Among men, farmers, heavy vehicle drivers and miners were most likely to be exposed to at least one carcinogen (see online supplementary table 4), while among women, farmers, drivers and transport workers were most likely to be exposed (see online supplementary table 5). Extrapolation of these figures to the Australian working population revealed that approximately 2 727 000 men (58.0%; 95% CI 56.2 to 59.9) and 877 100 women (20.6%; 95% CI 18.9 to 22.3), or 3 604 100 workers overall (40.3%; 95% CI 38.9 to 41.6), could be expected to be exposed to at least one of the priority carcinogens.

The most frequent exposure was solar radiation, with 37.0% of the Australian male working population and 7.9% of the female working population exposed (see tables 3 and 4). Diesel engine exhaust and environmental tobacco smoke were also common exposures, with over a million working men estimated to be exposed to each. In addition, more than 10% of the male

working population was exposed to each of benzene, lead and silica. Many of the other occupational carcinogens had small numbers of exposed workers in our dataset (as indicated by the wide CIs) and so the extrapolations should be regarded with caution.

## DISCUSSION

This study examined the current prevalence of exposure to occupational carcinogens among Australian workers. Overall, 37% of respondents were assessed as being exposed to at least one carcinogen, with exposures being more common among male workers, those who had completed a trade certificate and those residing in regional areas, after adjusting for occupation. These results are similar to those found in the NHEWS survey, where male workers were more likely to report being exposed to chemicals<sup>27</sup> and airborne hazards,<sup>26</sup> as well as the European Working Conditions Survey, where men were more likely to be exposed to 11 of the 13 physical risks studied.<sup>24</sup>

On extrapolation to the Australian working population, 3.6 million workers were estimated as being occupationally exposed

**Table 3** Proportion of final sample and Australian working population estimated to be occupationally exposed by carcinogenic agent, men

Carcinogen*	Most common occupational groups	Sample n (%)	Population n (%)	Population 95% CI†
Solar UVR	Farmer, animal/horticultural, painter	963 (34.8)	1 737 500 (37.0)	35.2 to 38.8
Diesel engine exhaust	Farmer, heavy vehicle driver, miner	796 (28.8)	1 344 500 (28.6)	26.9 to 30.3
ETS	Painter, plumber, hospitality	589 (21.3)	1 164 000 (24.8)	23.2 to 26.4
Benzene	Farmer, animal/horticultural, automobile driver	370 (13.4)	636 440 (13.5)	12.3 to 14.8
Lead	Painter, vehicle worker, plumber	295 (10.7)	502 100 (10.7)	9.6 to 11.9
Silica	Miner, construction, engineer	289 (10.5)	543 390 (11.6)	10.5 to 12.9
Wood dust	Carpenter, painter, handyperson	271 (9.8)	449 470 (9.6)	8.6 to 10.8
Artificial UVR	Farmer, vehicle worker, metal worker	247 (8.9)	391 770 (8.3)	7.4 to 9.4
PAHs	Farmer, emergency worker, food service	239 (8.6)	454 160 (9.7)	8.6 to 10.9
Shiftwork‡	Nurse, miner, passenger transport	203 (7.3)	396 120 (8.4)	7.4 to 9.5
Chromium VI	Painter, metal worker, carpenter	168 (6.1)	291 930 (6.2)	5.3 to 7.1
Asbestos	Vehicle worker, emergency worker, miner	138 (5.0)	251 960 (5.4)	4.6 to 6.3
Formaldehyde	Carpenter, painter, emergency worker	118 (4.3)	200 150 (4.3)	3.6 to 5.1
Nickel	Metal worker, plumber, vehicle worker	98 (3.5)	170 840 (3.6)	3.0 to 4.4
Ionising radiation	Health professional, miner, scientist	74 (2.7)	127 800 (2.7)	2.2 to 3.4
Trichloroethylene	Farmer, metal worker, plumber	44 (1.6)	73 570 (1.6)	1.2 to 2.1
Arsenic	Carpenter, office worker, heavy vehicle driver	33 (1.2)	49 750 (1.1)	0.8 to 1.5
Vinyl chloride	Emergency worker, machine operator	19 (0.7)	40 780 (0.9)	0.6 to 1.3
Ethylene oxide	Emergency worker, food factory, scientist	22 (0.8)	46 240 (1.0)	0.7 to 1.5
1,3-butadiene	Emergency worker	21 (0.8)	44 650 (1.0)	0.7 to 1.5
Cadmium	Metal worker, vehicle worker, electrical worker	13 (0.5)	20 840 (0.4)	0.2 to 0.7
Nitrosamines	Metal worker, scientist	8 (0.3)	14 710 (0.3)	0.1 to 0.6
Acid mists	Machine operator, metal worker, engineer	5 (0.2)	11 060 (0.2)	0.1 to 0.5

\*Includes only those priority carcinogens with five or more workers exposed.

†95% CI of the proportion.

‡Exposed to any one or more of seven shiftwork agents (light at night, phase shift, sleep disturbance, diet and chronodisruption, alcohol and chronodisruption, lack of physical activity, and vitamin D insufficiency).

ETS, environmental tobacco smoke; PAHs, polycyclic aromatic hydrocarbons; UVR, ultraviolet radiation.

to carcinogens. This represents approximately 40% of the Australian workforce. Exposures were not distributed evenly across occupational groups, with some groups having a much higher probability of exposure than others. For example, all of the heavy vehicle drivers and miners were estimated to be exposed, with the most frequent exposures being to diesel

engine exhaust and silica, respectively, while among other groups, such as cleaners and food factory workers, much smaller proportions of workers were exposed. Exposures were not limited to those occupations traditionally thought to be at high risk, but were seen across all groups, including those generally considered to be unexposed. For example, 9% of office

**Table 4** Proportion of final sample and Australian working population estimated to be occupationally exposed by carcinogenic agent, women

Carcinogen*	Most common occupational groups	Sample n (%)	Population n (%)	Population 95% CI†
Solar UVR	Farmer, handyperson, automobile driver	137 (6.2)	334 870 (7.9)	6.9 to 9.1
Diesel engine exhaust	Metal worker, heavy vehicle driver, miner	127 (5.7)	255 200 (6.0)	5.1 to 7.1
Shiftwork‡	Passenger transport, emergency worker, nurse	104 (4.7)	192 730 (4.5)	3.7 to 5.4
Benzene	Farmer, automobile driver, animal/horticultural	101 (4.5)	217 200 (5.1)	4.3 to 6.1
ETS	Construction, miner, heavy vehicle driver	86 (3.9)	247 360 (5.8)	4.9 to 6.8
Ionising radiation	Health professional, scientist, nurse	60 (2.7)	99 940 (2.3)	1.8 to 3.0
PAHs	Farmer, emergency worker, food service	58 (2.6)	104 720 (2.5)	1.9 to 3.3
Silica	Construction, miner, farmer	27 (1.2)	43 510 (1.0)	0.7 to 1.5
Wood dust	Carpenter, farmer, printer	20 (0.9)	28 850 (0.7)	0.4 to 1.2
Formaldehyde	Animal/horticultural, health professional, health support	16 (0.7)	29 390 (0.7)	0.4 to 1.2
Lead	Miner, vehicle worker, emergency worker	12 (0.5)	31 040 (0.7)	0.4 to 1.2
Artificial UVR	Metal worker, farmer, scientist	9 (0.4)	12 670 (0.3)	0.2 to 0.6
Ethylene oxide	Electrical worker, health professional, health support	7 (0.3)	12 970 (0.3)	0.2 to 0.6
Trichloroethylene	Farmer, nurse, office worker	6 (0.3)	8550 (0.2)	0.1 to 0.5

\*Includes only those priority carcinogens with five or more workers exposed.

†95% CI of the proportion.

‡Exposed to any one or more of seven shiftwork agents (light at night, phase shift, sleep disturbance, diet and chronodisruption, alcohol and chronodisruption, lack of physical activity, and vitamin D insufficiency).

ETS, environmental tobacco smoke; PAHs, polycyclic aromatic hydrocarbons; UVR, ultraviolet radiation.

workers were estimated to be exposed to occupational carcinogens, with the most frequent exposure being diesel engine exhaust. Therefore it appears that even within jobs conventionally thought to be at low or no risk of exposure, workers may still perform tasks which entail some potential exposure, such as driving or visiting construction sites.

Solar radiation was the most frequent exposure overall, with over 2 million workers, or 23%, exposed to significant solar radiation. This is somewhat lower than the estimate of sun exposure found in NHEWS (34%).<sup>25</sup> While it could be argued that this reflects an actual decrease in exposure over time, it is more likely a result of the differing exposure assessment methods used. In the NHEWS survey, respondents were asked directly about their exposure to predetermined categories of agents,<sup>27</sup> including 'direct sunlight', whereas in the current study, task-based questions were used to determine exposure. This latter method can be argued to provide for more sensitive and specific estimates of prevalence, as it captures exposures that workers may be unaware of or unable to report while disregarding innocuous and non-carcinogenic exposures.<sup>45</sup> It is however still possible that some exposures may have been missed by virtue of them not being included in the JSMs or rules, although every effort was made to preclude this possibility.

There are limitations to the approach used in this study, as exposure assessments were still based on self-report of tasks and may be subject to recall bias or social desirability constraints.<sup>46</sup> However, given that respondents were only required to answer questions regarding their current job tasks, it is unlikely that these biases would have had a substantial effect on the data obtained. Whereas retrospective exposure assessment may be limited by the respondents' memory, job-specific questions have been shown to provide accurate information with regard to exposures in the current job.<sup>45</sup> Another possible limitation of this study is the inclusion of only 38 carcinogens, which may have led to the exclusion of people exposed to carcinogens which were not on the list. The impact of this on the overall prevalence estimate obtained is however expected to be relatively minor, as the priority list included the common established carcinogens and anyone exposed to any of the less common carcinogens may well be exposed to one of the priority carcinogens, and therefore already have been taken account of in the estimate. We systematically identified the occupational carcinogens identified by IARC which were most likely to be present in Australia and found very low prevalences for some carcinogens, which suggests that we erred on the side of inclusivity.

The lower proportion of younger and migrant workers in the sample compared to the general population, and the resultant potential under-representation of particular occupations and industries, is another limitation of this study. This may have led to an underestimation of the prevalence of exposure. In addition, there is a potential bias arising from the relatively high number of refusals, non-responders and those with limited English language skills; however, the impact of this bias is unknown as we do not have any further information about non-participants. Further, the use of a cross-sectional study design, while providing for an accurate picture of current exposures, means that it is not possible to determine whether the exposures found here are likely to be enduring or only transitory.

## CONCLUSION

Overall, this study represents an important addition to the scientific literature, providing comprehensive information regarding exposure to occupational carcinogens in a developed economy (Australia) which has not previously been available. As well as

providing information on how many workers are likely to be exposed to carcinogens in the course of their work, the current study allows for an examination of the characteristics of exposed workers, finding exposures to be more common among male workers and those from regional areas. This may contribute to the health inequalities known to exist in the Australian population.<sup>47</sup>

Future research will use these data to estimate the lifetime risk of cancer likely to result from current occupational exposures and to investigate the theoretical impact on this risk of alternative exposure scenarios, such as closing certain industries or increasing the use of personal protective equipment. This will enable an assessment of how we might best intervene to reduce exposures and the subsequent risk of occupational cancer. The use of a population-based approach and consequent ability to capture exposures across a wide range of occupations, industries and demographic groups were particular strengths of this study, allowing for the investigation of exposures in all occupational groups, including those which have not traditionally been associated with carcinogenic exposures.

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**Contributors** RNC drafted this manuscript and conducted all statistical analyses under the direct supervision of LF, who directed the study and is responsible for its overall design. TRD, DCG, AR and GB were each involved in the design of the study and, together with SP, provided feedback on the draft of this manuscript. DCG, SP and AR also contributed to the data analysis process.

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## Supplemental Material

Web Only Table 1. Occupational groups with associated Australian and New Zealand Standard Classification of Occupation (ANZSCO) codes

Group	Included ANZSCO codes
Farmers	1211-1214 Farmers and Farm Managers
Hospitality	1411-1419 Accommodation and Hospitality Managers 4311-4319 Hospitality Workers
Engineers	2321 Architects and Landscape Architects 2322 Cartographers and Surveyors 2331-2339 Engineering Professionals 3121-3129 Building and Engineering Technicians
Scientists	2341-2349 Natural and Physical Science Professionals 3111-3114 Agricultural, Medical and Science Technicians 3993 Gallery, Library and Museum Technicians 4513 Funeral Workers
Painters	3322 Painting Trades Workers 3995 Performing Arts Technicians
Teachers	1343 School Principals 2411-2415 School Teachers 2421-2422 Tertiary Education Teachers 2491-2493 Miscellaneous Education Professionals
Nurses	2541-2544 Midwifery and Nursing Professionals 4114 Enrolled and Mothercraft Nurses
Other Health Professionals	2511-2519 Health Diagnostic and Promotion Professionals 2521 Chiropractors and Osteopaths

Supplementary Table 1 (cont)

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	2523-2527 Health Therapy Professionals
	2531-2539 Medical Practitioners
	4112 Dental Hygienists, Technicians and Therapists
Metal Workers	3221-3223 Fabrication Engineering Trades Workers
	3232-3234 Mechanical Engineering Trades Workers
	3994 Jewellers
	8217 Structural Steel Construction Workers
	8391 Metal Engineering Process Workers
Plumbers	3341 Plumbers
	8211 Building and Plumbing Labourers
Vehicle Workers	3211-3212 Automotive Electricians and Mechanics
	3231 Aircraft Maintenance Engineers
	3241-3243 Panelbeaters, and Vehicle Body Builders, Trimmers and Painters
	8994 Motor Vehicle Parts and Accessories Fitters
Carpenters	3312 Carpenters and Joiners
	3933 Upholsterers
	3941-3942 Wood Trades Workers
	3991 Boat Builders and Shipwrights
	8394 Timber and Wood Process Workers
Construction	3311 Bricklayers and Stonemasons
	3321 Floor Finishers
	3331-3334 Glaziers, Plasterers and Tilers
	8212-8215 Construction and Mining Labourers

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Supplementary Table 1 (cont)

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Electrical	3411 Electricians
	3421-3424 Electronics and Telecommunications Trades Workers
Food Factory	3511-3512 Food Trades Workers
	8311-8313 Food Process Workers
Food Service	3513-3514 Food Trades Workers
	8511-8513 Food Preparation Assistants
Printers	3921-3923 Printing Trades Workers
	3996 Signwriters
	7114 Photographic Developers and Printers
	8995 Printing Assistants and Table Workers
Animal and Horticultural	3611-3613 Animal Attendants and Trainers, and Shearers
	3621-3624 Horticultural Trades Workers
	8411-8419 Farm, Forestry and Garden Workers
Health and Personal Support	2522 Complementary Health Therapists
	2726 Welfare, Recreation and Community Arts Workers
	3911 Hairdressers
	4113 Diversional Therapists
	4115-4117 Health and Welfare Support Workers
	4211 Child Carers
	4221 Education Aides
	4231-4234 Personal Carers and Assistants
	4511 Beauty Therapists
	4515 Personal Care Consultants

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Supplementary Table 1 (cont)

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	4518 Other Personal Service Workers
Emergency Workers	1392 Senior Non-Commissioned Defence Force Members
	4111 Ambulance Officers and Paramedics
	4411-4413 Defence Force Members, Fire fighters and Police
	4421-4422 Prison and Security Officers
Outdoor Work NEC	2312 Marine Transport Professionals
	4514 Gallery, Museum and Tour Guides
	4521-4524 Sports and Fitness Workers
	5995 Inspectors and Regulatory Officers
	6111 Auctioneers and Stock and Station Agents
	6217 Street Vendors and Related Salespersons
	8992 Deck and Fishing Hands
Machine Operators	3931-3932 Textile, Clothing and Footwear Trades Workers
	3992 Chemical, Gas, Petroleum and Power Generation Plant Operators
	3999 Other Miscellaneous Technicians and Trades Workers
	7111-7113 Machine Operators
	7115-7119 Machine Operators
	7123 Engineering Production Systems Workers
	7129 Other Stationary Plant Operators
	8321-8322 Packers and Product Assemblers
	8392-8393 Miscellaneous Factory Process Workers
	8399 Other Factory Process Workers
Automobile Drivers	4512 Driving Instructors

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Supplementary Table 1 (cont)

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	5612 Couriers and Postal Deliverers
	6113 Sales Representatives
	6121 Real Estate Sales Agents
	7311 Automobile Drivers
	8997 Vending Machine Attendants
Heavy Vehicle Drivers	7121 Crane, Hoist and Lift Operators
	7211-7212 Mobile Plant Operators
	7219 Other Mobile Plant Operators
	7321 Delivery Drivers
	7331 Truck Drivers
	8216 Railway Track Workers
	8996 Recycling and Rubbish Collectors
Miners	7122 Drillers, Miners and Shot Firers
	8219 Other Construction and Mining Labourers
Warehousing	7213 Forklift Drivers
	7411 Storepersons
	8911 Freight and Furniture Handlers
Cleaners	8111-8116 Cleaners and Laundry Workers
Handypersons	8993 Handypersons
	8999 Other Miscellaneous Labourers
Passenger Transport	2311 Air Transport Professionals
	4517 Travel Attendants
	7312-7313 Automobile, Bus and Rail Drivers

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Supplementary Table 1 (cont)

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Office	1111-1113 Chief Executives, General Managers and Legislators
	1311 Advertising and Sales Managers
	1321-1325 Business Administration Managers
	1331-1336 Construction, Distribution and Production Managers
	1341-1342 Education, Health and Welfare Services Managers
	1344 Other Education Managers
	1351 ICT Managers
	1391 Commissioned Officers (Management)
	1399 Other Specialist Managers
	1421 Retail Managers
	1491-1499 Miscellaneous Hospitality, Retail and Service Managers
	2111-2114 Arts Professionals
	2121-2124 Media Professionals
	2211-2212 Accountants, Auditors and Company Secretaries
	2221-2223 Financial Brokers and Dealers, and Investment Advisers
	2231-2233 Human Resource and Training Professionals
	2241-2249 Information and Organisation Professionals
	2251-2254 Sales, Marketing and Public Relations Professionals

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Supplementary Table 1 (cont)

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2323-2326 Architects, Designers, Planners and Surveyors

2611-2613 Business and Systems Analysts, and Programmers

2621 Database and Systems Administrators

2631-2633 ICT Network and Support Professionals

2711-2713 Legal Professionals

2721-2725 Social and Welfare Professionals

3131-3132 ICT and Telecommunications Technicians

4516 Tourism and Travel Advisers

5111 Contract, Program and Project Administrators

5121-5122 Office and Practice Managers

5211-5212 Personal Assistants and Secretaries

5311 General Clerks

5321 Keyboard Operators

5411-5412 Call or Contact Centre Information Clerks

5421 Receptionists

5511-5513 Accounting Clerks and Bookkeepers

5521-5523 Financial and Insurance Clerks

5611 Betting Clerks

5613-5619 Clerical and Office Support Workers

5911-5912 Logistics Clerks

5991-5994 Miscellaneous Clerical and Administrative  
Workers

5996-5999 Miscellaneous Clerical and Administrative  
Workers

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Supplementary Table 1 (cont)

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6112 Insurance Agents

6211-6216 Sales Assistants and Salespersons

6219 Other Sales Assistants and Salespersons

6311 Checkout Operators and Office Cashiers

6391-6399 Miscellaneous Sales Support Workers

8912 Shelf Fillers

8991 Caretakers

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Web Only Table 2. Demographic Characteristics of Final Sample ( $N = 4,993$ ) Compared With the Australian Working Population According to the 2011 Census

Demographic Characteristic	% Final Sample	% Census <sup>a</sup>	<i>P</i> value <sup>b</sup>
Gender			0.689
Male	55.4	53.2	
Female	44.6	46.8	
Age			0.000
18-25	5.2	15.8	
26-35	12.4	22.9	
36-45	27.7	24.4	
46-55	33.7	23.2	
56-65	21.0	13.7	
Country of birth			0.047
Australia	79.6	70.7	
Other	20.4	29.3	
Language at home			0.000
English	98.1	81.5	
Other	1.9	18.5	
Highest education level			0.207
High school or less	37.1	37.4	
Trade certificate/diploma	28.0	34.8	
Bachelor degree or higher	34.9	27.8	
State of residence			0.991
New South Wales	34.6	31.2	
Victoria	24.5	25.2	

Queensland	18.2	20.2	
Western Australia	11.3	10.9	
South Australia	6.1	7.3	
Australian Capital Territory	2.2	2.0	
Tasmania	2.0	2.2	
Northern Territory	1.1	1.0	
Socioeconomic status <sup>c</sup>			0.923
First quintile (Lowest)	9.9	12.1	
Second	17.2	15.5	
Third	20.4	20.8	
Fourth	25.1	23.0	
Fifth quintile (Highest)	27.4	28.6	
Remoteness <sup>d</sup>			0.083
Major City	60.7	72.2	
Inner Regional	27.2	17.8	
Outer Regional	10.3	8.2	
Remote/Very Remote	1.8	1.8	

<sup>a</sup> Australian population aged 18 to 65 and currently employed as obtained from the 2011

Census of Population and Housing

<sup>b</sup> *P* value for difference between final sample and census population, obtained from  $\chi^2$  goodness of fit test

<sup>c</sup> From Socio-Economic Index for Areas Index of Relative Socio-economic Disadvantage (SEIFA IRSD)

<sup>d</sup> From Australian Standard Geographical Classification Accessibility/Remoteness Index of Australia (ARIA+)

Web Only Table 3. Proportion of Final Sample Estimated to be Possibly Exposed by Carcinogenic Agent and Gender

Carcinogen	Most Common Occupational Groups	Males	Females
		n (%)	n (%)
Acid mists	Emergency Worker, Carpenter, Office Worker	8 (0.3)	-
Asbestos	Plumber, Carpenter, Construction	202 (7.3)	5 (0.2)
Benzene	Emergency Worker, Cleaner, Construction	7 (0.3)	1 (0.04)
1,3-Butadiene	Construction, Emergency Worker, Scientist	16 (0.6)	-
Cadmium	Emergency Worker, Painter, Handyperson	49 (1.8)	6 (0.3)
Chromium VI	Farmer, Vehicle Worker, Metal Worker	226 (8.2)	18 (0.8)
Cobalt	Metal Worker	1 (0.04)	-
DEE	Warehousing, Machine Operator, Health Professional	2 (0.1)	1 (0.04)
Ethylene Oxide	Emergency Worker, Scientist	9 (0.3)	-
Formaldehyde	Emergency Worker, Construction, Scientist	29 (1.1)	11 (0.5)
Ionising Radiation	Office Worker	1 (0.04)	-
Lead	Electrical Worker, Handyperson, Construction	115 (4.2)	11 (0.5)
MOCA	Office Worker	2 (0.1)	-
Nickel	Painter, Handyperson, Farmer	40 (1.5)	16 (0.7)
Nitrosamines	Farmer, Animal/Horticultural, Handyperson	50 (1.8)	5 (0.2)
PCBs	Electrical Worker, Emergency Worker, Handyperson	55 (2.)	-
Silica	Metal Worker, Health Professional, Office Worker	5 (0.2)	-
Styrene-7,8-oxide	Construction, Metal Worker, Office Worker	10 (0.4)	1 (0.04)

Tetrachloroethylene	Emergency Worker, Cleaner, Machine Operator	25 (0.9)	3 (0.1)
Trichloroethylene	Emergency Worker, Cleaner, Construction	28 (1.0)	3 (0.1)
Vinyl Chloride	Emergency Worker, Scientist, Office Worker	12 (0.4)	-
Wood Dust	Printer, Construction, Machine Operator	10 (0.4)	2 (0.1)

DEE: Diesel Engine Exhaust

MOCA: 4,4'-Methylenebis(2-Chloroaniline)

PCBs: Polychlorinated Biphenyls

Web Only Table 4. Proportion of Final Sample Exposed to at Least One Carcinogen by Occupational Group, Males

Occupational Group (n, %) <sup>a</sup>	Most Common Exposures	n exposed (%)	95% CI <sup>b</sup>
Heavy Vehicle Drivers (142, 5.1)	DEE, Solar UVR, ETS	142 (100.0)	97.4, 100.0
Farmers (92, 3.3)	Solar UVR, DEE, PAHs	92 (100.0)	96.0, 100.0
Plumbers (69, 2.5)	Solar UVR, ETS, Lead	69 (100.0)	94.7, 100.0
Painters (23, 0.8)	Solar UVR, Lead, Wood dust	23 (100.0)	85.7, 100.0
Miners (22, 0.8)	Silica, DEE, Solar UVR	22 (100.0)	85.1, 100.0
Carpenters (85, 3.1)	Wood dust, Solar UVR, Formaldehyde	84 (98.8)	93.6, 99.8
Animal and Horticultural (68, 2.5)	Solar UVR, Benzene, DEE	67 (98.5)	92.1, 99.7
Vehicle Trades (78, 2.8)	DEE, Asbestos, Lead	76 (97.4)	91.1, 99.3
Handypersons (33, 1.2)	Solar UVR, Wood dust, Silica	32 (97.0)	84.7, 99.5
Passenger Transport (31, 1.1)	DEE, Shiftwork, Solar UVR	30 (96.8)	83.8, 99.4
Automobile Drivers (46, 1.6)	DEE, Solar UVR, ETS	41 (95.4)	77.0, 95.3
Engineers (84, 3.0)	Solar UVR, DEE, Silica	78 (92.9)	85.3, 96.7
Outdoor Work NEC (26, 0.9)	Solar UVR, DEE, Benzene	24 (92.3)	75.9, 97.9
Construction Workers (54, 1.9)	Silica, Solar UVR, ETS	49 (90.7)	80.1, 96.0
Electrical Workers (113, 4.1)	Solar UVR, ETS, Lead	101 (89.4)	82.4, 93.8
Emergency Workers (55, 2.0)	DEE, PAHs, Lead	49 (89.1)	78.2, 94.9

Metal Workers (101, 3.7)	Artificial UVR, Chromium VI, Nickel	88 (87.1)	79.2, 92.3
Warehousing (29, 1.1)	Solar UVR, DEE, ETS	25 (86.2)	69.4, 94.5
Scientists (37, 1.3)	Solar UVR, DEE, Benzene	29 (78.4)	62.8, 88.6
Other Health Professionals (53, 1.9)	Ionising radiation, PAHs, Solar UVR	39 (73.6)	60.4, 83.6
Machine Operators (56, 2.0)	Solar UVR, DEE, ETS	40 (71.4)	58.5, 81.6
Hospitality (21, 0.8)	ETS, Shiftwork, Solar UVR	15 (71.4)	50.1, 86.2
Nurses (19, 0.7)	Shiftwork, Ionising radiation, Artificial UVR	12 (63.2)	41.0, 80.9
Food Service (33, 1.2)	ETS, PAHs, Shiftwork	19 (57.6)	40.8, 72.8
Food Factory (32, 1.2)	Shiftwork, DEE, Ethylene oxide	13 (40.6)	25.5, 57.7
Printers (14, 0.5)	Artificial UVR, Formaldehyde, Wood dust	5 (35.7)	16.3, 61.2
Health and Personal Support (45, 1.6)	Ionising radiation, Shiftwork, Solar UVR	11 (24.4)	14.2, 38.7
Cleaners (31, 1.1)	Shiftwork, Silica, Solar UVR	6 (19.4)	9.2, 36.3
Teachers (119, 4.3)	Wood dust, Nickel, Lead	18 (15.1)	9.8, 22.7
Office Workers (1158, 41.9)	DEE, Solar UVR, ETS	167 (14.4)	12.5, 16.6
TOTAL (2766, 100.0)	Solar UVR, DEE, ETS	1466 (53.0)	51.1, 54.9

DEE: Diesel Engine Exhaust; ETS: Environmental Tobacco Smoke; PAHs: Polycyclic

Aromatic Hydrocarbons; UVR: Ultraviolet Radiation

<sup>a</sup> Percentage expressed is percentage of males falling into that occupational group

<sup>b</sup> 95% confidence interval of the proportion

Web Only Table 5. Proportion of Final Sample Exposed to at Least One Carcinogen by Occupational Group, Females

Occupational Group (n, %) <sup>a</sup>	Most Common Exposures	n exposed (%)	95% CI <sup>b</sup>
Farmers (28, 1.3)	Solar UVR, DEE, Benzene	28 (100.0)	87.9, 100.0
Automobile Drivers (20, 0.9)	DEE, Solar UVR, Benzene	20 (100.0)	83.9, 100.0
Passenger Transport (8, 0.4)	Shiftwork, DEE, ETS	8 (100.0)	67.6, 100.0
Heavy Vehicle Drivers (7, 0.3)	DEE, Solar UVR, ETS	7 (100.0)	64.6, 100.0
Handypersons (5, 0.2)	Solar UVR, ETS, DEE	5 (100.0)	56.6, 100.0
Electrical Workers (4, 0.2)	Solar UVR, ETS, DEE	4 (100.0)	51.0, 100.0
Vehicle Trades (3, 0.1)	DEE, Asbestos, ETS	3 (100.0)	43.9, 100.0
Metal Workers (2, 0.1)	Ionising radiation, DEE, formaldehyde	2 (100.0)	34.2, 100.0
Construction Workers (1, 0.04)	Silica, ETS	1 (100.0)	20.7, 100.0
Miners (1, 0.04)	Silica, Lead, Nickel	1 (100.0)	20.7, 100.0
Animal and Horticultural (24, 1.1)	Solar UVR, Benzene, DEE	22 (91.7)	74.2, 97.7
Engineers (7, 0.3)	Solar UVR, DEE, Benzene	6 (85.7)	48.7, 97.4
Emergency Workers (6, 0.3)	Solar UVR, Shiftwork, PAHs	5 (83.3)	43.7, 97.0
Scientists (42, 1.9)	Ionising radiation, DEE, Solar UVR	29 (69.1)	54.0, 80.9
Carpenters (3, 0.1)	Wood dust, DEE	2 (66.7)	20.8, 93.9
Hospitality (39, 1.8)	ETS, Solar UVR, PAHs	23 (59.0)	43.4, 72.9

Nurses (165, 7.4)	Shiftwork, Ionising radiation, PAHs	86 (52.1)	44.5, 59.6
Machine Operators (13, 0.6)	Solar UVR, DEE, ETS	6 (46.2)	23.2, 70.9
Food Service (45, 2.0)	ETS, PAHs, Shiftwork	20 (44.4)	30.9, 58.8
Food Factory (6, 0.3)	Shiftwork	2 (33.3)	9.7, 70.0
Outdoor Work NEC (3, 0.1)	Solar UVR, ETS	1 (33.3)	6.2, 79.2
Warehousing (3, 0.1)	ETS	1 (33.3)	6.2, 79.2
Other Health Professionals (53, 2.4)	Ionising radiation, Formaldehyde, DEE	17 (32.1)	21.1, 45.5
Printers (4, 0.2)	Solar UVR, Wood dust	1 (25.0)	4.6, 69.9
Health and Personal Support (188, 8.4)	Benzene, Solar UVR, Shiftwork	44 (23.4)	17.9, 29.9
Cleaners (50, 2.2)	Shiftwork, Silica	4 (8.0)	3.2, 18.8
Teachers (303, 13.6)	Silica, Solar UVR, Benzene	17 (5.6)	3.5, 8.8
Office Workers (1194, 53.6)	DEE, Benzene, Solar UVR	48 (4.0)	3.1, 5.3
TOTAL (2227, 100.0)	Solar UVR, DEE, Shiftwork	413 (18.6)	17.0, 20.2

DEE: Diesel Engine Exhaust; ETS: Environmental Tobacco Smoke; PAHs: Polycyclic

Aromatic Hydrocarbons; UVR: Ultraviolet Radiation

<sup>a</sup> Percentage expressed is percentage of females falling into that occupational group

<sup>b</sup> 95% confidence interval of the proportion