Occupational exposure to carcinogens in Australian road transport workers

Abstract

Background: Road transport workers (RTWs) are at high risk of exposure to several occupational carcinogens. However, there are gaps in knowledge regarding the extent and the circumstances of exposure. As a sub-study of the Australian Work Exposures Study, this study investigated the prevalence of occupational exposure in Australian RTWs. **Methods:** A random sample of Australian working population was invited to a telephone interview regarding their current jobs. An automated expert-assessment procedure was applied to self-reported job-related tasks using a web-based application. 162 RTWs were included in this study. **Results:** RTWs were exposed to diesel exhaust(97%), solar ultraviolet radiation(78%), environmental tobacco smoke(55%), benzene(29%), silica(15%) and asbestos(10%) at work. Besides driving on roads, vehicle maintenance-related tasks were the major source of carcinogen exposures among RTWs. **Discussion:** Most RTWs are exposed to at least one carcinogen at work. We have identified tasks where the use of control measures could potentially reduce exposures.

Keywords: Road transport workers; Occupational exposure; Cross-sectional survey; exposure prevalence

Introduction

Occupational exposure to carcinogens has been recognized as a largely preventable risk, with over 165 occupational carcinogens being identified by the International Agency for Research on Cancer (IARC) to date.(International Agency for Research on Cancer, 2013) Of these 165, 38 were considered to be relevant to Australian workplaces. (Fernandez et al., 2012) Identifying occupation-specific carcinogens would facilitate the reduction and elimination of such exposures, and thereby reduce future burden of cancer. Information on the circumstances of exposure is important to guide preventative actions. Of the job tasks which result in exposure to carcinogens, we need to know which ones are most often performed and whether control measures are optimally used.

Road transport workers (RTWs) are workers employed in the road transport sector who are directly involved in moving people or goods on roads. To be more specific, RTWs include lorry and van drivers, taxi drivers and chauffeurs, bus and coach drivers, and bicycle and motorbike delivery drivers (European Agency for Safety and Health at Work). In Australia, RTWs account for around 2% of the working-age population, with the majority of them being males. (Australinan Bureau of Statistics, 2011) It has been reported that RTWs are at higher risk of cancers, including malignant lymphomas, lung, bowel and skin cancer (Balarajan, 1983). Only a few studies have investigated occupational exposures to carcinogens among RTWs worldwide. All of them focused on specific agents such as benzene, diesel engine exhaust, ultraviolet radiation or whole body vibration. (Javelaud et al., 1998, Garshick et al., 1987, Glanz et al., 2007, Palmer et al., 2000) No study has yet quantified either the prevalence or level of occupational exposure to a wide range of carcinogens among RTWs.

The objectives of this paper are to identify (1) the prevalence of exposure to occupational carcinogens among RTWs in Australia and; (2) the circumstances of that exposure (e.g. the tasks undertaken and if protective equipment was available and used appropriately).

Methods

This study was a part of a larger study, the Australian Work Exposures Study (AWES). AWES was a cross-sectional telephone survey in 2012. The survey investigated occupational exposure prevalence

to 38 known or probable carcinogens in the Australian workplace.(Carey et al., 2014a) The details of the methodology of AWES have been described previously. (Carey et al., 2014a)

Data collection

The target population was the Australian working population aged 18 to 65 years. The AWES sample was randomly selected from a list of names provided by a commercial list broker (from sources including the residential White Pages). Holders of landline and mobile phone numbers were invited to participate in a computer-assisted telephone interview. Compared to those with unlisted numbers, those on the White Pages list were more likely to be older, Australian-born and in higher socioeconomic groups (Carey et al., 2014c). Demographic information was collected from all respondents. Information on the current job was then obtained (job title, main tasks at work, industry, frequency of work in terms of hours per week and weeks per year) and one of 58 job-specific modules (JSMs) was assigned to those whose job had potential exposure to one of the 38 pre-determined carcinogens.(Fernandez et al., 2012)

Each JSM asked participants questions about the tasks they did in their current job. The interviews were performed using a web-based platform called 'OccIDEAS', which automatically assigned exposures based on the answers to the task-based questions in respective JSMs.(Fritschi et al., 2009) The exposure rules were set prior to the interviews being conducted and were from the judgement of experienced occupational hygienists and exposure assessment experts.(Fritschi et al., 2009) Details of the survey methods have been described in previous publications.(Carey et al., 2014a, Peters et al., 2015) Participants were not asked to self-report their exposure, but rather were asked about tasks and exposures were inferred from these tasks. As an example, to assess diesel exhaust exposure during vehicle maintenance, respondents were asked if they worked on engines or did oil changes (vehicle maintenance tasks). If the answer was positive, a follow-up question was asked about the vehicle's fuel; if the answer was diesel fuel, an additional question was asked about whether a hose was attached to the exhaust pipe of the running vehicle to remove the exhaust. High exposure to diesel exhaust was indicated if workers reported doing vehicle maintenance work on diesel powered vehicles

without a hose attachment to the exhaust pipe. Otherwise, medium exposure was indicated. If the vehicle was not diesel powered, the worker was deemed not exposed to diesel exhaust from this task.

The target population in this study was RTWs in Australia. In accordance with the definition from the European Agency for Safety and Health at Work,(European Agency for Safety and Health at Work) truck drivers (Australia and New Zealand Standard Classification of Occupations (ANZSCO code 7331), recycling and rubbish collectors (8996), automobile drivers (7311), couriers and postal deliverers (5612), driving instructors (4512), delivery drivers (7321) and bus and coach drivers (7312) were included in this analysis. All RTWs were grouped into three occupational groups: on-road heavy-vehicle drivers (truck drivers, recycling and rubbish collectors); automobile drivers (automobile drivers, couriers and postal deliverers and driving instructors); and passenger transport workers (delivery drivers including motorcycle and bicycle delivery drivers and bus and coach drivers).

Participants were asked questions about vehicle type (e.g. truck, bus, car); driving conditions (e.g. metropolitan road, mine road, construction road); vehicle fuel type (e.g. diesel, petrol); vehicle maintenance related tasks (e.g. body work, brake); and material handling (e.g. loading or transporting materials). Additional questions covered time spent working outdoors and the use of sun protection measures, as well as their own smoking habits and those of their co-workers. Based on the responses to these task-based questions, RTWs were assessed regarding their potential for exposure to carcinogens including diesel exhaust, solar ultraviolet radiation (UVR), environmental tobacco smoke (ETS), benzene, silica and asbestos. Respondents were considered to be exposed to shiftwork if they regularly worked more than one shift in a row with at least one hour between midnight and 5.00 AM hours (graveyard shift) (Fritschi et al, 2013). Automatic assessments were made for probability of exposure (none, possible and probable) and the level of probable exposure (low, medium and high exposure). The assessment was then confirmed by project staff.

Residential postcode was applied to describe respondents' socio-economic status and remoteness. Socio-Economic Index for Areas Index of Relative Socio-economic Disadvantage (SEIFA IRSD) is

used as an indicator of socio-economic status. SEIFA IRSD summarises information about the economic and social conditions of people and households within an area, including both relative advantage and disadvantage measures. The higher index scores/quintiles represent more advantaged groups and vice versa. The Australian Standard Geographical Classification Accessibility/Remoteness Index of Australia (ARIA+) is an index of remoteness derived from measures of road distances between populated localities and service centres. ARIA is used in this study to indicate the remoteness of workers' residential area.

Statistical analysis

The demographic characteristics of the Australian working population of the target occupations were extracted from the 2011 Australian Census in order to compare the representativeness of the AWES respondents using Chi-square tests and Fisher's exact test, as appropriate.

Out of the 38 carcinogens measured in OccIDEAS, only the ones with more than five exposed RTWs were included in this study. Descriptive analysis was used with the exposure estimates. Chi-square/Fisher's exact tests were used to compare the difference in frequency of exposure with regard to demographic characteristics and occupational groups. The statistical significance value was set at $P<0.05$. Where statistically significant differences were found, post-sampling stratification and weights based on population data from the Australian Census were applied to the study sample to improve the reliability of population projections of occupational exposure to carcinogens. To be more specific, post-sampling stratification involves adjusting the sampling weights to the target population sizes within each stratum to decrease bias because of underrepresented groups in the population. Therefore, the estimated prevalence of exposures would better represent the exposure in the target population. Then, population extrapolations were performed by applying the estimated exposure prevalence to the total number of Australian RTWs from the 2011 Australian Census. All analyses were performed using Stata version 13.

Results

Seven thousand four hundred seventy six known eligible households were contacted and 5,528 AWES telephone interviews were completed, representing a 74% cooperation rate. In general, the AWES study respondents were representative of the Australian working population in terms of gender, education, socio-economic status, remoteness and state of residence. However, the respondents were slightly older and more likely to be Australian-born compared with the target population.(Carey et al., 2014a)

One hundred and sixty two RTWs were identified in the study sample; 88% (143/162) male and the majority (58%) aged between 35-54 years. Compared with the 2011 national Census data of working-aged RTWs in Australia, the sample underrepresented 18 to 34 year olds and those who lived in a major city (Table 1). Occupation-wise, the sample proportionally over-represented heavy vehicle drivers and slightly under-represented automobile drivers and passenger transport workers when compared to the national Census (Table 1). Therefore we weighted our sample by remoteness and occupational group to project the whole population exposure prevalence and the numbers of exposed RTWs in the Australian working population. All the percentages presented in the text and tables were weighted.

Table 1: Demographic characteristics of RTWs in AWES sample and Australian working population

The prevalence of occupational exposures to 38 carcinogens among RTWs were summarized in supplementary table 1. Fewer than 2% were exposed to each of lead compounds, wood dust, Polycyclic Aromatic Hydrocarbons other than from vehicle exhausts, and arsenic and these are not considered further. Therefore, in this study, occupational exposures to diesel exhaust, solar radiation, environmental tobacco smoke, benzene, shift work, silica, and asbestos were included because there were more than 5 exposed RTWs in out sample.

Table 2: Occupational exposure to selective carcinogens among Australian RTWs by socioeconomic status, remoteness and occupational groups

Based on our population projection, 96.7% RTWs in Australia were probably exposed to diesel exhaust, which was equivalent to about 270,000 Australian workers (Table 2). Of them, 65.4% and

3.9% respectively were exposed at medium and high levels (Table 2). Occupation-wise, automobile and heavy vehicle drivers were significantly more likely to expose to a higher level (medium/high level) than passenger transport workers; while workers living in major cities were significantly more likely to expose to medium/high level diesel exhaust (Table 2).

Solar UVR was the second most prevalent carcinogen to which RTWs were exposed. The estimated exposure proportion was 77.9% among Australian RTWs (extrapolated to 218,000 Australian RTWs), with 24.2% and 50.3% of them being exposed at medium and high levels respectively. Lower socio-economic group workers were more significantly likely to be exposed to solar UVR than those from higher socio-economic groups, while heavy vehicle drivers were significantly more likely to have high exposure (Table 2).

54.8% Australian RTWs were probably exposed to ETS (extrapolated to 153,000 Australian RTWs) and 4.5% were highly exposed. RTWs resident in major cities were significantly more likely to be exposed to ETS, while heavy vehicle drivers were significantly more likely to have high exposure (Table 2).

Around 28.5% Australian RTWs were probably exposed to benzene (extrapolated to 79,600 Australian RTWs); 24.6% were subject to medium exposure and 0.7% were potentially highly exposed (Table 2). Automobile drivers (65.4%) were significantly more likely to be exposed compared to the other occupational groups (Table 2).

22.8% Australian RTWs did shift work, equivalent to around 63,700 RTWs in Australia. It appears that workers from outer regional or remote areas and heavy vehicle drivers were more likely to do shift work compared to other groups respectively. However, the differences were not statistically significant.

14.9% Australian RTWs were potentially exposed to silica at a low level. All of the exposed persons were heavy vehicle drivers. In addition, workers from outer regional or remote areas were at significant higher risk of exposure (Table 2). 10.4% RTWs were probably exposed to asbestos at a

low level. Workers from lower socio-economic groups were at significant higher risk of exposure (Table 2).

Circumstances of exposure

Table 3: Main circumstances that lead to prevalence and level of exposure among Australian RTWs

Exposures to medium to high level diesel exhaust mainly derived from driving on major metropolitan roads, mine surfaces, construction sites or indoors; working around running diesel-powered vehicles; and servicing diesel-powered vehicles without tune-ups (Table 3).

The majority of RTWs (70.6%) worked more than 4 hours outdoors per day, which resulted in high exposure to solar UVR if insufficient sun protection measures (including using sunscreen, wearing a hat and cover-up clothing and working in the shade) were used (Table 3). With regard to sun protections, 90.9% Australian RTWs self-reported use of at least one sun protection measure (sunscreen, hat, clothing or working in shade) and more than 70.4% (95% CI: 59.9%, 79.2%) of them reported using more than one protection measure (Table 3).

The majority of ETS exposures (95.7%) happened at open spaces (e.g. outdoor or at building entrances) rather than in enclosed areas. Benzene exposure mainly occurred during driving and refilling petrol-powered vehicles (68.9%) and performing vehicle-body maintenance work (19.2%) (Table 3). Driving on construction or mine sites and handling materials containing silica were the sources of exposure to silica (Table 3). Also, Vehicle maintenance (brakes or clutches) was the major potential exposure circumstance (Table 3).

Of the high prevalence exposures among RTWs, multiple exposures to lung carcinogens including diesel exhaust, ETS, silica, and asbestos (in descending order) may put at higher risk of lung cancer. Therefore, multiple exposures to these carcinogens were summarized in Table 4. More than 60% of all RTWs were exposed to more than one lung carcinogen. Heavy vehicle drivers were more likely to have multiple exposures (diesel exhaust, ETS and silica).

Table 4: Multiple exposures among RTWs to lung carcinogens (Diesel exhaust, ETS, silica and asbestos)

Discussion

In this study, we investigated occupational exposure to carcinogens among RTWs in the Australian working population. Diesel engine exhaust, solar UVR and ETS were the most prevalent exposures among RTWs. Other exposures included benzene, shift work, silica and asbestos. The prevalence of exposure was generally higher among heavy vehicle drivers than other RTW occupational groups.

Diesel exhaust has recently been recognized as a lung and possible bladder carcinogen by IARC. (Benbrahim-Tallaa et al., 2012) Working with or close to diesel-powered equipment or vehicles in (semi-) enclosed conditions are the prime sources of diesel exhaust exposure, which puts RTWs, especially heavy vehicle drivers, at high risk of exposure. Use of protective measures should be mandated to reduce exposure to diesel exhaust where possible. For example, according to our estimate, 13.1% (95% CI: 6.2%, 25.6%) of Australian RTWs engage in vehicle maintenance tasks (e.g. servicing running diesel powered vehicles) which lead to high level diesel exhaust exposure, but only 1 out of 8 workers self-reported using an extraction hose that was attached to the exhaust pipe. Therefore, regulations should be enforced on the use of extraction hoses attached to the exhaust pipe on running engines during maintenance.

The most efficient way to reduce diesel exhaust exposure is to upgrade diesel emission standards to Euro 6/US2010 and to replace 'traditional engines' and 'transitional engines' with 'new technology diesel engines', which, compared to the 'traditional engines', reduce 99% emission of particulate mass and 98% of NO_x.(Scheepers and Vermeulen, 2012) Until now, Australia is behind other developed countries in this endeavour. The US and Europe have completed the transition for on-highway diesel vehicles to Euro 6/US2010 standard in 2007 and 2013 respectively, while the Euro 6/US2010 standard has not been introduced in Australia yet.(Scheepers and Vermeulen, 2012) In our study, we project 69.3% (65.4+3.9%) of Australian RTWs were medium or highly exposed to diesel exhaust, which is more than five times the prevalence in the Australian working population (13.4%).(Peters et al., 2015) RTWs are one of the most exposed occupational groups in Australia but diesel exhaust exposure is also common among motor vehicle mechanics (81.4%), farmers/gardeners (69.0%) and miners/quarrymen (68.8%).(Peters et al., 2015)

Solar UVR has been recognized as one of the most prominent risk factors for skin cancer, especially in Australia. 78% of RTWs in Australia were probably occupationally exposed to solar UVR compared to the overall estimation of 22% of the entire Australian working population.(Carey et al., 2014b) Furthermore, more than 50% of all RTWs were subject to high level exposure to solar UVR by working more than 4 hours outdoors per day without adequate protection. Despite this, the majority of RTWs (91%) self-reported using at least one UV protection method for more than 50% of the time outdoors. The most commonly reported protective measures included protective clothing (78%), wearing a hat (56%) and working in the shade (45%). However, only 31% of the RTWs reported using sunscreen properly. These results are consistent with findings from other similar studies in Australia and Canada.(Gies and Wright, 2003, Shoveller et al., 2008) Given the nature of sun protection measures, full UV protective measures should be used to reduce exposure, especially when the UV index levels are above 3.(Australian Safety and Compensation Council, 2008) Our study indicated that only 8.9% of the probably exposed RTWs used all four protective measures for more than half the time spent working outdoors, which is comparable to the 8.7% prediction of the entire Australian working population in the AWES study.(Carey et al., 2014b) To further reduce occupational solar UV exposure, interventions should be focused upon improving the use of sunscreen among RTWs.

More than half of RTWs were probably exposed to ETS. Workers in major cities (61.5%) had a higher potential ETS exposure prevalence than other regions. These findings seem to be contradictory to the report of national smoking rates from the Australian Health Survey, in which a positive correlation was observed between smoking rates and the remoteness of areas; and an inverse correlation observed with socio-economic status.(Australian Bureau of Statistics, 2012) However, considering the increasing information about the harms of, and regulations against, smoking in public in major cities in Australia, it is possible that people in major cities were more aware of potential exposure to ETS than those from outer or remote regions, which may have led to reporting bias in this study.

Approximately 25% of Australian RTWs were exposed to benzene at medium or high levels. Furthermore, RTWs were also potentially exposed to low level silica (14%) and asbestos (10%). In terms of multiple exposures, performing vehicle maintenance and handling carcinogen-containing materials were the main source of multiple exposures to lung carcinogens. Proper precautionary measures and procedures need to be implemented including the use of exhaust pipe during vehicle maintenance or bottom loading tankers with vapour recovery rather top loading.

This is the first study describing occupational exposure to carcinogens in RTWs on a population basis. Methodologically the exposure assessment was performed systematically based on workers' self-reported occupational tasks combined with standard task-based exposure assessment rules and procedures developed by occupational hygienists.(Fritschi et al., 2009) This automated expert-assessment procedure is more objective than self-reported exposures by workers which rely heavily on the awareness and knowledge of respondents to potential exposure to carcinogens.(McGuire et al., 1998) In addition, given automated expert-assessment procedure is based on tasks within a job, it is arguably a more valid method to assess exposure than using Job Exposure Matrices (JEMs), in which all workers with the same job titles are assigned the same occupational exposure.(McGuire et al., 1998) Finally, in OccIDEAS, the exposure assessments are developed specifically for the Australian context by occupational exposure experts (occupational hygienists and physicians) based on the application of available exposure data and their professional knowledge and experience. The experts identified tasks that may lead to exposure and the control measures that are in use. Questions are tailored to identify the extent of exposure experienced by the individuals. OccIDEAS then allocates exposure none, possible, probable and high, medium or low to individuals based on their answers.(Fritschi et al., 2009)

On the other hand, the comprehensiveness and accuracy of exposure assessment is bound by the knowledge of common tasks undertaken by Australian workers and expert's inputs about the source and determinants of carcinogen exposures associated with these tasks. Since AWES is a cross-sectional telephone survey, it is impossible to include all tasks performed in every occupation. Therefore, our study could potentially underestimate prevalence of occupational exposures by missing

out relatively uncommon tasks performed by workers in specific occupations. However, this should not have major impact on the estimates. Furthermore, given the lack of a gold standard in occupational exposure assessment, it is recommended that the exposure assessment could be made by occupational hygienists based on their knowledge and understanding of jobs and tasks. Other work has shown that the expert assessment of occupational exposures demonstrated high rating accuracy in both concentration and frequency of exposure against industrial hygiene measurements.(Fritschi et al., 2003) OccIDEAs was developed by consulting a panel of experienced Australian occupational hygienists assessing Australian working conditions. Therefore, compared to other existing measurement tools, the application of OccIDEAs is more relevant to Australian industry and government decision makers. However, this may not be the case in other countries. Also, since AWES is a cross-sectional study, it provides a snapshot of occupational exposure in 2012 by asking questions about current jobs. It was not designed to quantify the cumulative occupational exposures to carcinogens for individual workers. We did not ask information regarding duration of current job. Neither did we ask questions about commute time in this study. However, exposures encountered during commuting to work are not generally considered occupational exposures.

Finally, representativeness is a major concern of survey studies including AWES. In this study, our samples of RTWs were not representative of the target Australian RTWs. Therefore, post-sampling stratification/population weights were applied to the analysis to modify the projection of population exposure prevalence of carcinogens. This method is widely used in large scale surveys to adjust representativeness of study samples.

In conclusion, most RTWs in Australia were exposed to at least one of the following carcinogens: diesel exhaust, solar UVR, ETS, benzene, shift work, silica and asbestos. Interventions should be imposed to those high prevalence high-risk tasks to reduce future exposure.

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Ethics Approval

The study was approved by the University of Western Australia Human Research Ethics Committee

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Table 1: Demographic characteristics of RTWs in AWES sample and Australian working population

Demographic Characteristic	RTWs in AWES n (%)	RTWs in 2011Australian Census [a] n(%)	Chi2 p-value
Total	162 (100)	280,035 (100)	
Gender			0.14
Male	143 (88.3)	257,305 (91.9)	
Female	19 (11.7)	22,730 (8.1)	
Country of birth			**0.01**
Australia	141 (87.0)	194,029 (75.7)	
Others	21 (13.0)	62,177 (24.3)	
Age Group			**<0.01**
18-34	14 (8.7)	62,058 (22.2)	
35-54	93 (57.8)	149,091 (53.2)	
55-64	54 (33.5)	68,887 (24.6)	
Highest education level			0.07
High school or less	125 (77.2)	184,606 (65.9)	
Trade certificate or diploma	30 (18.5)	79,892 (28.5)	
Bachelor degree or higher	7 (4.3)	15,537 (5.6)	
Socioeconomic status[b]			0.22
Highest 2 quintiles	50 (30.9)	105009 (37.7)	
3rd quintile	38 (23.5)	66,412 (23.9)	
Lowest 2 quintiles	74 (45.7)	106,939 (38.4)	
Remoteness[c]			**<0.01**
Major city	82 (50.6)	185,160 (66.3)	
Inner regional	59 (36.4)	57,637 (20.6)	
Outer regional/Remote/very remote	21 (13.0)	36,597 (13.1)	
Occupational groups			**0.03**
Automobile	30 (18.5)	66,784 (23.9)	
Heavy Vehicle	111 (68.5)	152,930 (54.6)	
Passenger transport	21 (13.0)	60,321 (21.5)	

** May not always add up to total as some data was missing from both census and study*
a. 2011Australian Census from Australian Bureau of Statistics (ABS)
b. Socio-Economic Index for Areas Index of Relative Socio-economic Disadvantage (SEIFA IRSD):summarises information about the economic and social conditions of people and households within an area, including both relative advantage and disadvantage measures. the higher index scores/quintiles represent more advantaged groups, vice versa
c. Australian Standard Geographical Classification Accessibility/Remoteness Index of Australia (ARIA+): indexes of remoteness derived from measures of road distances between populated localities and service centres

Table 2: Occupational exposure to selective carcinogens among Australian RTWs by socioeconomic status, remoteness and occupational groups

Carcinogens	Total	Socioeconomic status			Remoteness			Occupational groups		
		4--5	3	1--2	Major city	Inner regional	Outer regional/remote	Auto-mobile	Heavy vehicle	Passenger transport
N	162	74	38	50	**82**	**59**	**21**	**30**	**111**	**21**
Diesel exhaust										
Probable exposure (n)	**156**	**70**	**38**	**48**	**79**	**57**	**20**	**26**	**109**	**21**
Population % (%; CI)	**96.7 (92.2, 98.7)**	95.3 (86.6, 98.5)	100	96.9 (88.3, 99.2)	96.4 (89.6, 98.8)	95.9 (84.8, 99.0)	100	*89.7 (72.0, 96.7)*	*98.3 (92.4, 99.6)*	*100*
Population projection (n)	**270,171**									
Medium exposure (n)	**97**	**50**	**21**	**26**	**62**	**26**	**9**	**22**	**64**	**11**
Population % (%; CI)	**65.4** (57.6, 72.4)	69.7 (57.3, 79.7)	65.8 (49.9, 78.8)	57 (42.6, 70.2)	*75.9 (65.1, 84.2)*	*44.1 (30.8, 58.3)*	*42.5 (24.3, 62.9)*	*76.9 (58.7, 88.6)*	*62.7 (53.0, 71.4)*	*60.5 (40.6, 77.4)*
High exposure (n)	**8**	**1**	**5**	**2**	**4**	**4**	**0**	**0**	**8**	**0**
Population % (%; CI)	**3.9** (1.8, 7.9)	1.3 (0.2,8.9)	10.6 (4.1, 24.9)	3.5 (0.8, 14.5)	*4.1 (1.6, 10.2)*	*5.3 (2.0, 13.3)*	*0/0*	*0*	*7.0 (3.3, 14.1)*	*0*
Solar UVR										
Probable exposure (n)	**133**	**57**	**31**	**45**	**65**	**47**	**21**	**24**	**98**	**11**
Population % (%; CI)	**77.9 (70.5, 83.9)**	*71.1 (58.9, 80.9)*	*74.9 (55.2, 87.8)*	*92.9 (83.0, 97.3)*	*75.1 (64.8, 83.2)*	*74.9 (61.2, 84.9)*	*100*	*78.2 (58.9, 90.0)*	*89.8 (82.4, 94.3)*	*47.6 (27.7, 68.2)*
Population projection (n)	**217,646**									
Medium exposure (n)	**40**	**17**	**8**	**15**	**18**	**15**	**7**	**7**	**27**	**6**
Population % (%; CI)	**24.2** (17.9, 32.1)	21.4 (13.2, 32.8)	16.2 (7.7, 31.1)	35.9 (22.9, 51.3)	21.9 (14.1,32.5)	25.1 (15.2, 38.5)	36.7 (18.6, 59.6)	*26.9 (13.6, 46.1)*	*23.2 (15.9, 32.5)*	*24.6 (11.0, 46.1)*
High exposure (n)	**87**	**37**	**22**	**28**	**45**	**30**	**12**	**16**	**67**	**4**
Population % (%; CI)	**50.3** (42.6, 58.0)	46.2 (34.9, 57.8)	55.8 (37.9, 72.4)	53.8 (39.6, 67.5)	50.9 (40.6,61.1)	47.1 (37.0, 57.5)	52.9 (31.9, 72.9)	*47.5 (30.4, 65.2)*	*63.3 (53.3, 72.2)*	*20.3 (7.7, 43.8)*
ETS										
Probable exposure (n)	**88**	**40**	**14**	**34**	**53**	**24**	**11**	**19**	**62**	**7**
Population % (%; CI)	**54.8 (46.7, 62.6)**	52.4 (40.6, 63.9)	42.1 (26.0, 60.1)	68.9 (54.1, 80.7)	*61.5 (50.6, 71.3)*	*37.4 (25.5, 51.0)*	*47.3 (26.6, 69.1)*	*62.8 (44.2, 78.2)*	*60.3 (50.6, 69.3)*	*32.6 (15.8, 55.6)*
Population projection (n)	**153,106**									
High exposure (n)	**9**	**2**	**2**	**5**	**4**	**4**	**1**	**0**	**9**	**0**
Population % (%; CI)	**4.5** (2.3, 8.7)	2.7 (0.7, 10.0)	4.6 (1.0, 18.7)	7.8 (3.0, 18.7)	4.1 (1.6, 10.2)	5.3 (2.0, 13.3)	5.3 (0.7, 29.7)	*0*	*8.1 (4.1, 15.5)*	*0*
Benzene										
Probable exposure (n)	**47**	**21**	**12**	**14**	**25**	**17**	**5**	**19**	**27**	**1**
Population % (%; CI)	**28.5 (22.6, 35.2)**	26 (17.5, 36.8)	33.6 (20.0, 50.7)	29.2 (18.0, 43.7)	29.3 (22.1, 37.8)	29.5 (18.6, 43.4)	21.3 (8.4, 44.2)	*65.4 (46.3, 80.5)*	*23.3 (16.0, 32.7)*	*3.7 (0.6, 19.6)*
Population projection (n)	**79,626**									
Medium exposure (n)	**39**	**16**	**11**	**12**	**23**	**13**	**3**	**18**	**20**	**1**

Population % (%; CI)	**24.6** (19.0, 31.2)	21.4 (13.5, 32.0)	30.7 (17.6, 47.9)	25.9 (15.4, 40.3)	27.1 (19.9, 35.6)	24.2 (14.2, 38.0)	10.6 (2.7, 33.8)	*61.5 (42.5, 77.6)*	*17.9 (11.4, 26.9)*	*3.7 (0.6, 19.6)*
High exposure (n)	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Population % (%; CI)	**0.7** (0.1, 4.7)	1.3 (0.2,08.9)	0	0	1 (0.1, 6.9)	0	0	*0*	*1.2 (0.2, 8.4)*	*0*
Shift work										
Probable exposure (n)	39	14	11	14	19	14	6	2	34	3
Population % (%; CI)	22.8 (16.7, 30.3)	24.7 (14.9, 38.1)	30.3 (16.4, 48.9)	18.8 (11.0, 30.3)	22.6 (14.7, 33.0)	18.6 (11.7, 28.4)	31.9 (15.7, 54.0)	7.7 (1.9, 26.1)	30.9 (22.5, 40.9)	17.7 (6.1, 41.7)
Population projection (n)	**63,701**									
Silica										
Probable exposure (n)	**31**	**11**	**5**	**15**	**8**	**14**	**12**	**0**	**31**	**0**
Population % (%; CI)	**14.9 (10.9, 20.0)**	11.2 (6.2, 19.5)	10.3 (3.9, 24.1)	25.4 (15.8, 38.2)	*8.1 (4.2, 15.1)*	*18.6 (11.7, 28.4)*	*47.8 (29.2, 67.1)*	*0*	*26.8 (19.5, 35.7)*	*0*
Population projection (n)	**41,629**									
Medium exposure (n)	**1**	1	0	0	**0**	**0**	**1**	**0**	**1**	**0**
Population % (%; CI)	0.6 (0.1, 4.0)	1.2 (0.2, 7.6)	0	0	*0*	*0*	*5.3 (0.7, 29.7)*	0	1.1 (0.2, 7.1)	0
Asbestos										
Probable exposure (n)	**21**	**4**	**7**	**10**	**8**	**12**	**1**	**2**	**18**	**1**
Population % (%; CI)	**10.4 (6.6, 15.9)**	*4.1 (1.4, 11.5)*	*14.9 (6.7, 29.9)*	*18.7 (9.8, 32.8)*	*8.7 (4.4, 16.4)*	*18.6 (10.3, 31.1)*	*5.3 (0.7, 29.7)*	7.7 (1.9, 26.1)	14.1 (8.6, 22.1)	3.7 (0.6, 19.6)
Population projection (n)	**29,057**									

All the prevalence rates and CI presented were weighted to the 2011 Australian census RTW data;

Person chi square test (Rao and Scott correction) applied to exposures and socioeconomic status/remoteness/occupational groups; significant differences ($p<0.05$) were highlighted using *Italic*

Table 3: Main circumstances that lead to prevalence and level of exposure among Australian RTWs

Main Circumstances resulting in carcinogen exposure	Total n % (%,95%CI)	Exposure Levels		
		High	Medium	Low
Diesel Exhaust	**156**	**8**	**97**	**51**
Vehicle maintenance	44 23.1% (17.4, 29.9)	7 92.8% (60.7, 99.1)	22 18.0% (11.7, 26.5)	15 25.7% (15.4, 39.5)
Driving	113 77.5% (70.6, 83.2)	5 57.6% (22.6, 86.3)	93 98.5% (93.8, 99.6)	15 35.1% (21.9, 51.1)
Working around running vehicles	19 9.0% (5.5, 14.2)	3 21.7% (6.3, 53.4)	12 9.7% (5.3, 16.9)	4 5.5% (1.9, 15.2)
Solar UV	**133**	**87**	**40**	**6**
Spent >4 hours outdoors/day	96 70.6% (61.3, 78.4)	87 100%	9 25.6% (12.1, 46.3)	0
1-4 hours outdoors /day	32 25.0% (17.7, 34.2)	0	31 74.4% (53.7, 87.9)	1 9.1% (1.1, 46.6)
< 1 hour outdoors/day	5 3.3% (1.3, 8.1)	0	0	5 90.9% (53.4, 98.9)
UV- protection measures:				
Sunscreen >50% of the time outdoor	38 30.7% (22.1, 40.9)	18 22.8% (13.4, 36.1)	17 45.0% (28.7, 62.4)	3 34.2% (9.3, 72.5)
Hat >50% of the time outdoor	80 55.5% (44.8, 65.6)	46 44.8% (34.3, 55.8)	30 75.3% (58.1, 87.1)	4 54.7% (17.5, 87.3)
Protective clothing >50% of the time outdoor	104 77.6% (67.5, 85.2)	71 81.3% (68.1, 89.8)	28 71.5% (53.8, 84.4)	5 70.2% (22.0, 95.2)
Working in shades >50% of the time outdoor	55 44.9% (35.2, 55.1)	34 37.0% (25.5, 50.1)	20 63.8% (48.3, 76.9)	1 9.0% (1.1, 46.2)
Number of UV protection measures:				
0	9 9.1% (4.2, 18.7)	4 8.5% (2.7, 23.6)	4 7.8% (2.9, 19.6)	1 29.8% (4.8,78.0)
1	30 20.4% (13.3, 30.0)	24 26.6% (16.6, 39.8)	5 9.4% (3.6, 22.6)	1 15.6% (2.5, 56.8)
2	45 32.1% (25.6,39.5)	32 35.3% (25.6, 46.3)	12 27.6% (18.2, 39.5)	1 20.5% (2.8, 69.4)
3	39 29.4% (20.8, 39.8)	27 29.6% (19.1, 42.8)	10 29.5% (15.1, 49.6)	2 25.2% (5.5, 66.1)
4	10 8.9% (4.1, 18.4)	0 0	9 25.6% (12.1, 46.2)	1 9.0% (1.1, 46.2)
ETS	**88**	**9**	**0**	**79**
Other people smoke indoor	9 8.2% (4.1, 15.6)	9 100%	n/a	0
Other people smoke at entrance/outdoor	84 95.7% (88.7, 98.4)	5 47.7% (18.4, 78.6)	n/a	79 100%
Benzene	**47**	**1**	**39**	**7**
Vehicle Maintenance (body work)	12 19.2% (10.9, 31.4)	0	12 22.2% (12.7, 35.8)	0
Drive and refill petrol powered vehicles	28 68.9% (55.4, 79.6)	0	28 80.3% (67.2, 89.0)	0
Handling petroleum products and refill	6 13.4% (5.9, 27.4)	1 100%	0	5 76.9% (39.9, 94.4)
Silica	**31**	**0**	**1**	**30**
Drive on construction/mine sites	17 54.4% (35.8, 71.9)	0	0	17 56.8% (37.5, 74.1)
Handling materials containing silica	17 53.4% (35.0, 70.9)	0	0	17 55.7% (36.8, 73.0)
Asbestos	**21**	**0**	**0**	**21**
Vehicle maintenance (brakes or clutches)	16 74.7% (50.1, 89.6)	0	0	16 74.7% (50.1, 89.6)

note: Only exposure circumstances with more than 5 cases were reported & the exposure circumstances are not mutually exclusive, thus the numbers may not add up to total number.

All the prevalence rates and CI presented were weighted to the 2011 Australian census RTW data

Table 4: Multiple exposures among RTWs to lung carcinogens (Diesel Exhaust, ETS, silica and asbestos)

No. of exposures	RTWs	Automobile drivers	Heavy vehicle drivers	Passenger transport workers
	N; % (95% CI)*			
0	**2** 0.9% (0.2, 3.4)	**1** 2.6% (0.4, 14.5)	**1** 0.5% (0.07,3.5)	**0**
1	**58** 38.1% (30.5, 46.3)	**12** 38.5% (22.4, 57.5)	**33** 27.8% (19.8, 37.5)	**13** 6.4% (41.0, 81.5)
2	**76** 47.9% (39.7, 56.2)	**16** 55.1% (36.7, 72.2)	**52** 49.6% (39.7, 59.4)	**8** 36.3% (18.5, 59.0)
3	**18** 9.8% (6.2, 15.2)	**1** 3.8% (0.5, 23)	**17** 16.1% (9.9, 24.9)	**0**
4	**8** 3.4% (1.6, 7.0)	**0**	**8** 6.1% (2.9, 12.5)	**0**

Multiple exposures to Diesel exhaust, ETS, silica and asbestos; *Prevalence rates and CI were weighted to the Australian RTW population

Supplementary files:

Table 1: Exposure to all carcinogens by occupational groups

Agent	All RTWs (n=162)	Heavy vehicle drivers (n=111)	Automobile drivers (n=30)	Passenger Transport (n=21)
Diesel exhaust	156 (96.3)	109 (98.2)	26 (86.7)	21 (100)
Solar radiation	133 (82.1)	98 (88.3)	24 (80.0)	11 (52.4)
Environmental Tobacco Smoke (ETS)	88 (54.3)	62 (55.9)	19 (63.3)	7 (33.3)
Benzene	47 (29.0)	27 (24.3)	19 (63.3)	1 (4.8)
Shift work	39 (24.1)	34 (30.6)	2 (6.7)	3 (14.3)
Silica	31 (19.1)	31 (27.9)	0	0
Asbestos	21 (13.0)	18 (16.2)	2 (6.7)	1 (4.8)
Lead compounds	3 (1.8)	2 (1.8)	0	1 (4.8)
Wood dust	2 (1.2)	2 (1.8)	0	0
Polycyclic Aromatic Hydrocarbons (PAHs)[a]	1 (0.6)	0	1 (0.9)	0
Arsenic	1 (0.6)	1 (0.9)	0	0
Leather dust	0	0	0	0
Beryllium	0	0	0	0
Cadmium	0	0	0	0
Chromium (VI)	0	0	0	0
Cobalt metal	0	0	0	0
Nickel compounds	0	0	0	0
Artificial ultraviolet radiation	0	0	0	0
Ionising radiation	0	0	0	0
Radon-222	0	0	0	0
Acid mists	0	0	0	0
Acrylamide	0	0	0	0
Alpha-Chlorinated toluene	0	0	0	0
1, 3-Butadiene	0	0	0	0
Diethyl sulphate	0	0	0	0
Dimethyl sulphate	0	0	0	0
Epichlorhydrin	0	0	0	0
Ethylene oxide	0	0	0	0
Formaldehyde	0	0	0	0
Glycidol	0	0	0	0
4, 4'-Methylenebis (2-chloroaniline) (MOCA)	0	0	0	0
Nitrosamines[f]	0	0	0	0
***Ortho*-Toluidine (2-Aminotoluene)**	0	0	0	0
Polychlorinated biphenyls (PCBs)[e]	0	0	0	0
Styrene-7, 8-oxide	0	0	0	0
Tetrachloroethylene (Perchloroethylene)	0	0	0	0
Trichloroethylene	0	0	0	0
Vinyl chloride	0	0	0	0

Table 2: Solar UV exposure assessment

UV (Solar radiation) aJSM	UV Radiation	**Comments**
1. How many hours per day do you usually spend working outdoors? - greater than 4 - between 1 and 4 hours - less than 1 hour	T H* M* L*	 * if >50% for all 4 protection methods, then MEDIUM * if >50% for all 4 protection methods, then LOW * if >50% for all 4 protection methods, then NO exposure
2. In which city/region do you usually work? [free text]		
3. Do you work with or near reflective surfaces such as sand, glass, roofing iron, water? Y/N/DK, see 3.1 3.1 Please specify the type of reflective surfaces you work near [free text]	T	Ground reflection: grass, soil and water reflect less than 10% of UV radiation; fresh snow reflects as much as 80%; dry beach sand about 15% and sea foam about 25%. (WHO 2002)
4. How often do you wear sunscreen when working outdoors? - less than 50% of time spent outdoors - more than 50% of the time spent outdoors	T R	 Rule: If >50% for all 4 protection methods then decrease exposure level by 1
5. How often do you wear a hat when working outdoors? - less than 50% of time spent outdoors - more than 50% of the time spent outdoors	T R	 Rule: If >50% for all 4 protection methods then decrease exposure level by 1
6. How often do you wear clothing that covers most of your body (i.e. Knee length shorts and shirts or t-shirts with sleeves) when working outdoors? - less than 50% of time spent outdoors - more than 50% of the time spent outdoors	T R	 Rule: If >50% for all 4 protection methods then decrease exposure level by 1
7. How often do you work in the shade when working outdoors? - less than 50% of time spent outdoors - more than 50% of the time spent outdoors	T R	 Rule: If >50% for all 4 protection methods then decrease exposure level by 1