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Exposure to noise and ototoxic chemicals in the Australian workforce

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Exposure to noise and ototoxic chemicals in the Australian workforce

Abstract

Objective: To determine the current prevalence of exposure to workplace noise and ototoxic chemicals, including co-exposures.

Method: A cross sectional telephone survey of nearly 5000 Australian workers was conducted using the web-based application, OccIDEAS. Participants were asked about workplace tasks they performed and predefined algorithms automatically assessed worker's likelihood of exposure to ten known ototoxic chemicals as well as estimated their full shift noise exposure level ($L_{Aeq,8h}$) of their most recent working day. Results were extrapolated to represent the Australian working population using a raked weighting technique.

Results: In the Australian workforce, 19.5% of men and 2.8% of women exceeded the recommended full shift noise limit of 85dBA during their last working day. Men were more likely to be exposed to noise if they were younger, had trade qualifications and did not live in a major city. Men were more likely exposed to workplace ototoxic chemicals (57.3%) than women (25.3%). Over 80% of workers who exceeded the full shift noise limit were also exposed to at least one ototoxic chemical in their workplace.

Conclusion: The results demonstrate that exposures to hazardous noise and ototoxic chemicals are widespread in Australian workplaces and co-exposure is common. Occupational exposure occurs predominantly for men and could explain some of the discrepancies in hearing loss prevalence between genders.

What this paper adds

What is already known about this subject?

- Occupational noise exposure is a known major cause of hearing loss globally. Workplace chemicals can also damage the ears and auditory pathways and, in some cases, co-exposure of chemicals with noise can potentiate noise-induced hearing loss.

What are the new findings?

- Almost one in five working men were exposed above the Australian full shift occupational limit for noise ($L_{Aeq,8h}$ >= 85dB) on their most recent working day.
- The most common workplace ototoxic exposures were to toluene, p-xylene, ethylbenzene, n-hexane, styrene and carbon monoxide.
- Four out of five workers who exceeded the full shift noise exposure limit were also likely to be exposed to at least one ototoxic chemical in their workplace.

How might this impact on policy or clinical practice in the foreseeable future?

- Despite regulations recommending engineering or administration controls to reduce workplace noise, high levels of noise exist in many Australian workplaces.
- The high prevalence of co-exposures to noise and ototoxic chemicals represents an additional risk for workers.

- Strategies must be developed to reduce workplace noise and ototoxic exposure, especially in industries where high prevalence of co-exposure exists.

Introduction

Hearing loss affects over half a billion people worldwide[1] and is a leading cause of years lived with disability.[2] A loss of hearing can significantly reduce an individual's quality of life as it is associated with social isolation, poor mental health, and cognitive decline.[3,4] Hearing loss also has nationwide economic impacts through loss of productivity in the workforce, increased welfare payments and substantial direct health system costs.[5]

It has been estimated that 16% of all disabling hearing loss in adults worldwide is due to occupational noise.[6] In Australia, there were 16,500 successful worker's compensation claims for occupational hearing loss between 2002 and 2007.[7]

Occupational hearing loss was originally used to describe hearing loss caused by workplace noise but has been revised to include hearing loss due to other occupational hazards, including some ototoxic chemicals.[8]Ototoxic chemicals include organic solvents, metals, and asphyxiates that can cause damage to the inner ear or the auditory pathways.[9] Increased risk of hearing loss can occur when exposure to some ototoxic chemicals occurs independently of noise or it can potentiate noise induced hearing loss when co-exposed with noise.[9] A study of naval shipyard workers found that those exposed to workplace metals and/or solvents had 2.4 times higher odds of developing hearing loss than those exposed to low levels of metal, solvents and noise.[10] Choi and Kim [11] found that the odds of hearing loss was 2.1 fold higher for those who were co-exposed to noise and organic solvents than those only exposed to occupational noise.

If a worker's $L_{Aeq,8h}$ exceeds the limit of 85dBA they are at risk of developing hearing loss.[12] Overall workforce exposure prevalence of those at risk has been estimated by extrapolating noise measurement data from industry-specific noise surveys.[13] However, samples are not always representative and data do not exist for all occupations. Questionnaires[14] allow for more representative estimates, but to date, questionnaires have only collected information about general workplace noise levels and validity is lacking.

Research into workplace ototoxic chemicals is still in its infancy. Although some data on ototoxic exposure in specific industries exist, little is known about who is at risk at a population level and, importantly, who has the additional risk of co-exposure with workplace noise.

The Australian Workplace Exposure Survey (AWES)-Hearing was designed to determine: the prevalence of hazardous workplace noise and ototoxic chemical exposure in the Australian workforce; the characteristics of workers exposed to noise above the occupational limit; the most commonly used ototoxic chemicals in Australian workplaces; the occupations and industries in which ototoxic exposure is occurring; and the prevalence of co-exposure to ototoxins and noise. Results will allow policy makers to obtain comprehensive understanding of the current exposures in workplaces that increase the risk of hearing loss and hence to target control measures.

Methods

Survey Methods

AWES-Hearing was a nationwide, cross sectional survey performed between July 2016 and March 2017 using computer-assisted, telephone interviews.

A randomly generated list of both mobile and landline telephone numbers was provided by a sample survey company (Sampleworx) to the research team. Landline numbers were representative by area for Australian population and had been cleaned to remove businesses and unregistered numbers. A third of the sample were mobile numbers, which were randomly generated within known Australian in-use number ranges.

Stratified sampling was used to achieve 2700 and 2300 completed interviews for men and women respectively (54%:46%) in order to represent the gender distribution of the Australian working population.[15] Randomly generated gender tags using a 7:1 men to women ratio were assigned to each telephone number to account for the increased difficulty in recruiting men compared to women. Interviewers asked for a man or woman depending on the predefined gender tag for each telephone number. If there was no person of that gender at that number or the number was non-residential then no interview was conducted. For land lines, if more than one person of the tagged gender was in the household then the individual with the next birthday was asked to participate. Each telephone number was called six times at different times of the day before being deemed "unable to contact".

The target population was the Australian working population aged 18-64 years who had worked in paid employment within the last seven days. If their most recent working day was over a week ago an appointment to conduct the interview was made after their next working day. Those too ill to complete the interview and those who did not speak adequate English or could not adequately hear the interviewer were excluded.

This study was approved by the Curtin University Human Research Ethics Committee.

Data Collection

The interview was conducted using the OccIDEAS V3 software.[16] OccIDEAS is a tool that is used to collect information on tasks done by workers. It uses evidence-based algorithms to relate those tasks to the exposures incurred. It contains over 50 job modules, which comprise questions asking specifically about tasks carried out by a particular job group (e.g. health professionals, construction workers). The questionnaire-based algorithm that evaluates an individual worker's noise exposure has been validated and demonstrated an excellent ability to identify construction workers with an $L_{Aeq,8h} \geq 85$dBA.[17]

After the study was explained, the participant had to give verbal consent before the questionnaire was commenced. Firstly demographic data were collected, then the interviewer asked for the person's job title and description of their job role and, based upon these, chose the most appropriate job module for the participant. Once a job module was chosen, OccIDEAS automatically stepped the interviewer through the questionnaire.

All job modules had two sections. The first contained questions used to determine if a participant was regularly exposed to ototoxic chemicals at any time during their employment. The second section asked questions relating to noise exposure and the tasks performed during their most recent working shift. Interviews took between 5 and 20 minutes, depending on the job selected and the participant's answers.

Exposure Assessment

In order to establish a priority list of workplace ototoxins, we considered all substances identified as "ototoxic" and "possibly ototoxic" from the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) group[18], those with a level Category 1 and Category 2 level of evidence of ototoxicity to humans by the Nordic Expert Group[9], and those regarded as having "good evidence" for ototoxicity on the more inclusive EU-OSHA list.[19] Only chemicals which had evidence of auditory effects at exposure concentrations near the Australian relevant 8-hour time weighted average occupational exposure limits (TWA OEL)[20] were considered, regardless whether the effect occurred with or without noise exposure (Table 2).

We developed rules to assign exposure to tasks within OccIDEAS with reference to existing literature, reference texts, reports, material safety data sheets, equipment specification sheets and expert knowledge. Questions related to the participant's general working environment, tasks regularly performed and protective measures used. We determined the probability of exposure for each task in the interview and categorised them as follows: tasks where the chemical is likely to be present but at levels that would be of little concern (classified as probable low); tasks where exposures would be measurable but unlikely to exceed OELs (probable medium); and tasks with exposures highly likely to require monitoring for compliance (probable high). As the durations of the tasks undertaken were unknown, and some were likely to be short, exposures could not be directly related to TWA OEL. When a worker undertook more than one task resulting in exposure for the same chemical, the highest level of exposure was used.

Noise exposure was defined as $L_{Aeq,8h}$≥85dBA in line with the Australian National Standard for Occupational Noise.[12] A validated algorithm was designed to use the information collected about the workers most recent working shift to estimate a full shift workplace noise exposure level ($L_{Aeq,8h}$).[17] Through the OccIDEAS questionnaire, noisy tasks, equipment and tools the worker used during their most recent working shift were determined as well as how long each task was performed. Using a library of predetermined noise levels (L_{Aeq}), the software assigned a level for each task/tool and calculated partial exposures using the mathematical formula: $E_{A,T_i} = 4.T_i.10^{0.1(L_{Aeq,T_i}-100)}$where T_i represents the time associated with each task and $L_{Aeq,Ti}$ the noise level in dBA of the task [21]. The partial exposures are then summed and the result is normalised to an 8-hour shift using the formula: $L_{Aeq,8h} = 10log_{10}\left[\frac{E_{A,T}}{3.2 * 10^{-9}}\right]$.

Statistical Analysis and Extrapolation to Australian Population

Using the job title and description of job role, each respondent's job was classified using the Australian and New Zealand Standard Classification of Occupation (ANZSCO).[22] These codes were then grouped into 43 groups using the two digit codes. Occupation groups were further combined using the ANZSCO categories and were different for men and women because of reduced numbers in some groups (online supplementary table S1). For example, trade workers, mobile plant operators and drivers were combined for women.

Statistical analysis was conducted using Stata V14[23] and statistical computing language R.[24] We weighted our data using a raking technique[25] to adjust for the mismatch between our sample and the Australian working population according to available Australian Census data.[15,26] Postcodes were used to determine the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD)[27] and remoteness area[28] for each participant using the Australian Bureau of Statistics (ABS) 2011 Census Data.

The variables age group, education, remoteness, state of residence, social economic status (IRSAD), Australian/New Zealand born (yes/no) and occupational group (as shown in table 1) were used in the raking by forced insertion. If an individual had missing data in one or more of these seven variables their raking weight was based upon their remaining known variables. The raking was performed with the R function ‘anesrake’ in package ‘anesrake’.[29]

Results

Of the 128,418 telephone numbers called, 73,924 (60.3%) were disconnected, business numbers, fax/modem or no contact was made after six attempts (figure 1). Thirty-eight per cent were ineligible with incorrect gender and age the most common reasons for illegibility. Of the 5815 eligible contacts, 86.1% completed the interview. An $L_{Aeq,8h}$ could not be estimated for 14 completed interviews due to missing task times (table 1).

A total of 498 (10.0%; 95%CI 9.2 - 10.9) workers in our sample population had an estimated $L_{Aeq,8h} \geq$ 85dBA. When extrapolated to the Australian working population, 1.1 million (11.5%) Australians were exposed above the occupational limit for noise on their most recent working day. The majority of exposed workers (88.3%) were men. Given the much higher prevalence of exposures for men, they are the primary focus of our results and discussion, however all data for women are reported in the tables or in supplementary information.

Men who were younger, with trade qualifications or high school only education, and those in regional/remote areas were most likely to be exposed to noise (table 1). Men in farming, construction, automotive and machine operation roles had the highest prevalence of exposure. Forty-seven per cent of men working in the construction industry exceeded the full shift occupation limit for noise on their most recent working day and the majority of automotive workers (61.7%) and machine operators (64.5%) were also exposed over the 85dBA limit. Women were most likely to be exposed to hazardous noise levels if they were employed in farming (17.8%) or trade/driving occupations (26.7%) (table 1).

Over half (50.8%, 95% CI 49.4 to 52.2) of our sample undertook at least one task during their employment that resulted in exposure to one or more ototoxic chemicals, with most of those exposed (85.3%) estimated to be exposed at a probable medium or probable high level. Weighted results show that over 4.1 million Australians (41.9% of the workforce) were probably exposed to at least one ototoxic chemical at a probable medium or high level during the course of their employment with 71.0% of these workers being men. (table 2)

The most common ototoxic exposures were to toluene, p-xylene, ethylbenzene, n-hexane, styrene and carbon monoxide (CO) (table 2). When considering only those exposed at a probable medium or probable high level, the most common exposures were toluene in men (23.0%) and CO in both men (53.6%) and women (24.2%). CO exposure at high levels was estimated to occur for 12.2% (95% CI 10.6 to 13.8) of male workers and 1.4% (95% CI 0.8 to 2.1) of female workers; which equates to over 681,000 Australian workers (Supplementary table S5). The tasks associated with probable medium or probable high ototoxic exposure to toluene were those associated with paints, degreasers, solvent based glues, mineral spirits, and refuelling of generators or petrol equipment. Probable medium or high CO exposure was primarily associated with vehicle and generator exhaust and, to a lesser extent, exposure to pyrolysis products (e.g. back burning).

Of the 1.1 million workers exposed over the noise limit ($L_{Aeq,8h} \geq$85dBA) on their most recent working day, 890,000 (80.0%) were also regularly exposed to an ototoxic chemical at a probable medium or high level (Supplementary table S4). The most common ototoxic chemical exposures in those also exceeding the noise limit were toluene and CO (table 2).Co-exposure to both noise and at least one ototoxic chemical occurred most commonly for male automotive workers (57.7%) construction workers (41.7%) and machine operators (45.7%).

Discussion

This study, AWES-Hearing, has estimated the nation-wide prevalence of workplace exposure to both noise and ototoxic chemicals. Results show that despite workplace regulations, on any working day 11.8% of the Australian population have an $L_{Aeq,8h}$ over 85dB.

In addition, our results show that in Australia four out of five workers exposed to full shift noise over the 85dBA exposure limit also have probable medium/high exposure to at least one ototoxic chemical in their workplace. As some ototoxic chemicals can exacerbate hearing loss when co-exposure occurs with noise[9], this is an important finding. It demonstrates that most of those who work in hazardous noise environments may have additional risk of hearing loss associated with co-exposure to ototoxic chemicals.

Our results show that noise and ototoxic exposures in the workplace are much more common in men than women, supporting the premise that workplace exposure plays a part in the gender difference in hearing loss prevalence mainly due to differences in employment patterns by gender. As hearing loss causes significant physical, mental and social dysfunction[30], the prevention of occupational hearing loss should be a key focus in preserving men's health in middle and older ages.

We achieved an 86.1% response rate of those eligible. Our sample was similar to the Australian working population[26] with small differences in IRSAD and occupational groups (data not shown). Our sample was also slightly older than the Australian population with 26% men and 24% women aged above 55 years compared to 16% for both genders in the population.[26] The largest discrepancies could be seen in education level where 41% of men and 47% of women in our sample had a university degree, compared with 26% and 33% of the Australian working population.[26]

The AWES-Hearing questionnaire included questions about hearing protection worn, however this information was not used when estimating each workers $L_{Aeq,8h}$ because the Australian standard for noise specifies that hearing protection should not be taken into account when calculating a worker's $L_{Aeq,8h}$.[31] Personal hearing protection is not always effective in protecting hearing because it is often not fitted properly and not always worn when needed.[32]

It is difficult to compare this study to other national surveys of noise exposure as it is the first to use a validated questionnaire specifically focused on the most recent working day, rather than a self-report of general workplace noise levels. The AWES-Hearing study results should be comparable to workplace noise surveys that measure full shift exposures, although it is difficult to find noise surveys that had similar occupation categorisation and are a representative sample of the population. In the United States (US), personal noise dose measurements collected from road construction workers found that 45.4% had an L_{Aeq8h} over 85dBA.[33] Our OccIDEAS validation study found that 46% of construction workers were likely to be exposed over 85dBA.[17] These values are similar to the prevalence of 47.1% for construction workers observed in this AWES-Hearing study. A US study using data from the 1980s found high prevalences of ototoxic chemical exposure in similar economic sectors to the ones we identified: construction; transportation; automotive services; and manufacturing workers. [34]

Although some regulators recognise the auditory risk some workplace chemicals create[35], most current workplace limits do not yet reflect this, perhaps due to the lack of human studies to quantify the dose-response relationships. It has been found that co-exposures of ototoxic chemicals and noise can potentiate the risk of hearing loss when exposure levels are below occupational limits.[36] Both the US Army[37] and SafeWork Australia[38] recommend monitoring a worker's hearing level if they are exposed to 50% or more of the workplace exposure standard for ototoxic chemicals. In the American Conference of Governmental Industrial Hygienists [ACGIH] 2018 booklet[39] the TLV® for Audible Sound includes a note that periodic audiograms are advised for any worker exposed to noise and to Carbon monoxide, Hydrogen cyanide, Lead, and solvent mixtures. Audiograms are also advised for any exposure to ethyl benzene, styrene, toluene or xylene.

The level at which CO affects the auditory system is unclear, although several human studies have suggested there may be a possible ototoxic effect below current range of international OELs. AWES-Hearing results showed that over half of all Australian working men are exposed to CO at a probable medium or probable high level, with the majority classified as probable medium exposure. Medium exposure suggests these workers undertake tasks that expose them to a level of CO that is measurable but unlikely to exceed OELs. Given the high prevalence of workplace CO exposure, quantifying the dose-response relationship of CO and hearing loss (with or without noise) should be a research priority.

Limitations

As in most surveys, selection bias is a limitation. However, this study was designed to achieve the most representative sample of the Australian working population possible. Random digit dialling reduced selection bias and mobile telephone numbers were used to reach younger workers. As women are more likely to participate in telephone surveys, we stratified by gender. Gender tags associated with each phone number prevented an over representation of women who did not live with a male willing to complete the questionnaire. Because of our selection criteria, we had a very high number of ineligible calls, however, of those eligible, we achieved a very high response fraction (86.1%). As a result of these efforts our sample was reasonably representative of the Australian working population, although slightly older and more educated.

The exclusion of those who were hearing impaired (0.01%) could have led to a slight underestimation of the prevalence. However, these individuals will include some who had non-occupational hearing loss e.g. congenital deafness or presbycusis. Thus, there will be a negligible effect on risk estimates.

Unfortunately we could not make precise ototoxic chemical exposure categories as exposures are estimated for a wide range of workplaces with differing work rates and control measures. There are also intra- and inter-worker and day-to-day variations in exposure.

A further limitation is that noise exposure results are based on the most recent working day and may not be a true indication of worker's typical noise exposure. However, averaging across the whole working population of Australia reduces this error. $L_{Aeq,8h}$ estimations also rely on task-based noise level derived from the literature which may introduce another source of error.

This study is based on self-reported tasks and task times that could be subject to recall bias. However, since, for noise exposure, only recent occupational exposures in the last working day were queried rather than exposures during a lifetime, recall bias may be reduced. Once again averaging also reduces this error. A systematic review performed in 2018 concluded that although only moderate accuracy of self-reported duration of tasks can be achieved at an individual level, self-reports can be viable at a group level.[40]

The noise questionnaire was validated in construction workers with a wide array of jobs and tasks,[17] however it has not been validated in every occupation in the study.

Conclusion

Occupational hearing loss is preventable, yet our results show that 11% of the Australian working population were exposed above the OEL for noise on their most recent working day. We have also highlighted the widespread use of ototoxic chemicals in Australian workplaces and that the majority (80%) of those exposed to noise are also exposed to at least one ototoxic chemical in their workplace. Occupational exposure occurs predominantly for men and could explain some of the discrepancies in hearing loss prevalence between men and women.

The situation is likely to be similar in other high-income countries and maybe worse in low and middle-income countries. In order to reduce the future burden of hearing loss, immediate action into reducing workplace risk factors must be undertaken.

Figure 1. Flow diagram of response

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Table 1. Numbers and percent of subjects in AWES-hearing sample who are exposed to noise above L_{Aeq8} of 85dBA on their last working day by different characteristics and the extrapolated proportion in the Australian working-age population, stratified by gender. (N = 4977)

	Men - sample		**Men - Australian working population**			**Women - sample**		**Women – Australian working population**		
	n	**%**	**%**	**95% CI**	**n**	**n**	**%**	**%**	**95% CI**	**n**
Total	2689	16.7	19.5	17.6-21.4	982182	2288	2.2	2.8	1.9-3.7	129900
Missing	10					4				
Age group										
18-24	234	21.8	19.1	13.1-25.1	122179	201	4.0	3.7	0.6-6.7	23114
25-34	431	17.4	21.1	16.5-25.6	262278	351	1.4	0.9	0.0-2.0	9836
35-44	569	18.5	21.6	17.6-25.6	258471	488	1.8	3.0	1.0-4.9	32004
45-54	755	14.4	17.3	14.0-20.5	196526	708	2.5	3.5	1.7-5.4	38660
55-64	700	15.6	17.4	13.9-20.9	142728	540	2.0	3.6	1.2-6.0	26286
Education										
High school or less	712	21.3	19.6	16.2-23.0	346028	570	3.0	2.2	0.8-3.6	37660
Trade or apprenticeship	407	36.6	35.2	29.9-40.5	490607	49	12.2	12.2	3.1-21.4	61191
Diploma	436	18.1	15.0	10.9-19.0	89308	581	2.6	1.7	0.4-2.9	13824
University degree	1100	5.3	4.3	2.9-5.7	56239	1075	1.2	1.1	0.4-1.8	17225
Missing n(%)	34(1.3%)					13(0.6%)				
Remoteness										
Major Cities	1769	12.7	15.7	13.5-17.8	568820	1484	1.6	2.1	1.1-3.0	69239
Inner Regional	520	24.8	30.5	25.6-35.4	263375	423	2.8	5.3	2.5-8.1	41826
Outer Regional	309	24.6	26.9	20.6-33.2	117859	290	3.8	4.4	0.7-8.0	16509
Remote/Very Remote	71	25.4	26.4	14.5-38.4	32128	65	6.2	2.6	0.0-8.2	2326
Missing n(%)	20(0.7%)					26(1.1%)				
Occupational group										
Office	225	0.4	0.5	0.0-1.6	1525	544	0.6	0.3	0.0-0.9	3419
IT & engineering	358	6.1	5.0	2.1-7.8	25439	104	3.8	3.0	0.0-7.0	5531
Managers	327	7.0	11.3	6.7-15.8	56831	179	0.0	0.0		0
Professionals	227	0.4	0.2	0.0-0.9	576	245	0.4	0.6	0.0-1.9	2439
Education	94	4.3	4.5	0.0-9.7	6012	231	0.9	0.5	0.0-1.6	1649
Farming	178	34.8	35.7	27.1-44.3	73339	56	17.9	17.8	3.4-32.3	14374

Hospitality/entertainment	177	7.3	7.6	2.8-12.3	36167	167	3.0	1.2	0.0-3.4	6030
Retail	115	4.3	4.7	0.3-9.1	15735	173	1.2	2.2	0.0-4.9	11747
Personal service	103	13.6	12.1	4.9-19.4	31037	94	4.3	5.1	0.0-10.6	13674
Trades & drivers (W)						89	19.1	26.7	11.9-41.6	66293
Construction (M)	187	47.6	47.1	38.6-55.6	256824					
Drivers (M)	184	14.7	18.6	11.9-25.3	78761					
Automotive (M)	142	60.6	61.7	52.7-70.7	172017					
Other trades (M)	135	26.7	25.6	16.6-34.7	65319					
Machine operators (M)	103	60.2	64.5	53.4-75.6	155191					
Health professionals (W)						238	0.8	0.7		2428
Health support (W)						168	0.6	0.5		2315
Health (M)	134	3.0	3.5	0.0-7.3	7408					

M = men, W = women

Table 2. Numbers of subjects in AWES-hearing sample (N=4994) and extrapolated proportion in the total Australian population exposed to ototoxic chemicals with and without co-exposure to noise (estimated L_{Aeq8} > 85dBA) by gender and different ototoxic chemicals.

	Men - sample		**Men - population**			**Women - sample**		**Women - population**		
Exposure	**N exposed**	**% exposed**	**% exposed**	**95% CI**	**N exposed**	**N exposed**	**% exposed**	**% exposed**	**95% CI**	**N exposed**
Probable exposure to any level ototoxic chemical (low, medium and high)										
Toluene	1589	58.9	60.6	58.2-62.9	3053556	745	32.5	29.6	27.1-32.1	1381622
p-xylene	1581	58.6	60.1	57.8-62.5	3031611	743	32.4	29.6	27.1-32.1	1380969
Ethylbenzene	1509	55.9	57.0	54.7-59.4	2875302	677	29.5	26.2	23.8-28.6	1222761
n-hexane	1527	56.6	57.8	55.5-60.2	2916076	694	30.3	27.1	24.7-29.6	1265646
Trichlorethylene	84	3.1	2.1	1.5-2.8	108016	8	0.3	0.2	0.0-0.4	8335
Styrene	1335	49.5	51.2	48.8-53.6	2580691	532	23.2	21.6	19.3-23.8	1006990
Carbon monoxide	1571	58.2	60.7	58.4-63.0	3060531	716	31.2	29.6	27.1-32.1	1382082
Lead	194	7.2	8.8	7.5-10.2	444759	14	0.6	1.0	0.5-1.6	47264
Mercury	4	0.1	0.1	0.0-0.2	4560	7	0.3	0.3	0.0-0.6	14618

Carbon disulphide	2	0.1	0.0	0.0-0.1	1305	1	0.0	0.2	0.0-0.5	10179
Any ototoxic	1701	63.0	66.1	63.9-68.4	3333939	835	36.4	35.0	32.4-37.7	1635282
Probable medium or probable high level exposure to ototoxic chemicals*										
Toluene	560	20.7	23.0	21.0-25.0	1158895	58	2.5	2.9	2.0-3.9	137174
p-xylene	155	5.7	6.1	5.0-7.3	309002	9	0.4	0.6	0.2-1.0	27780
Ethylbenzene	45	1.7	1.6	1.0-2.2	82376	4	0.2	0.3	0.0-0.5	11667
n-hexane	189	7.0	7.2	6.0-8.4	362614	10	0.4	0.7	0.2-1.1	30542
Trichlorethylene	17	0.6	0.6	0.3-1.0	31939	1	0.0	0.0	0.0-0.1	923
Styrene	218	8.1	8.7	7.3-10.0	437424	9	0.4	0.6	0.2-1.1	29386
Carbon monoxide	1445	53.5	53.6	51.3-56.0	2704838	626	27.3	24.2	21.8-26.5	1127900
Lead	110	4.1	4.6	3.6-5.5	229473	2	0.1	0.1	0.0-0.2	2730
Any ototoxic	1513	56.1	57.3	54.9-59.6	2887959	650	28.4	25.3	22.9-27.7	1182071
Co-exposures of noise with probable medium or probable high exposure to ototoxic chemicals*										
Noise + toluene	249	9.3	10.7	9.2-12.2	538763	16	0.7	1.0	0.4-1.5	44480
Noise + p-xylene	74	2.8	3.4	2.5-4.2	170036	2	0.1	0.4	0.1-0.8	20397
Noise + ethylbenzene	23	0.9	1.0	0.5-1.4	49311	2	0.1	0.2	0.0-0.5	10661
Noise + n-hexane	93	3.5	3.9	3.0-4.8	197446	2	0.1	0.4	0.1-0.8	20397
Noise + trichloroethylene	8	0.3	0.3	0.1-0.6	16258	0				0
Noise + styrene	107	4.0	4.3	3.4-5.3	218121	3	0.1	0.5	0.1-0.8	21855
Noise + carbon monoxide	348	12.9	14.3	12.7-16.0	722845	26	1.1	1.7	1.0-2.4	79340
Noise + lead	64	2.4	2.7	1.9-3.5	136248	2	0.1	0.1	0.0-0.2	2735
Noise + any ototoxic	379	14.1	16.0	14.2-17.7	804553	31	1.4	1.8	1.1-2.6	85741

*No exposed subjects to mercury or carbon disulphide

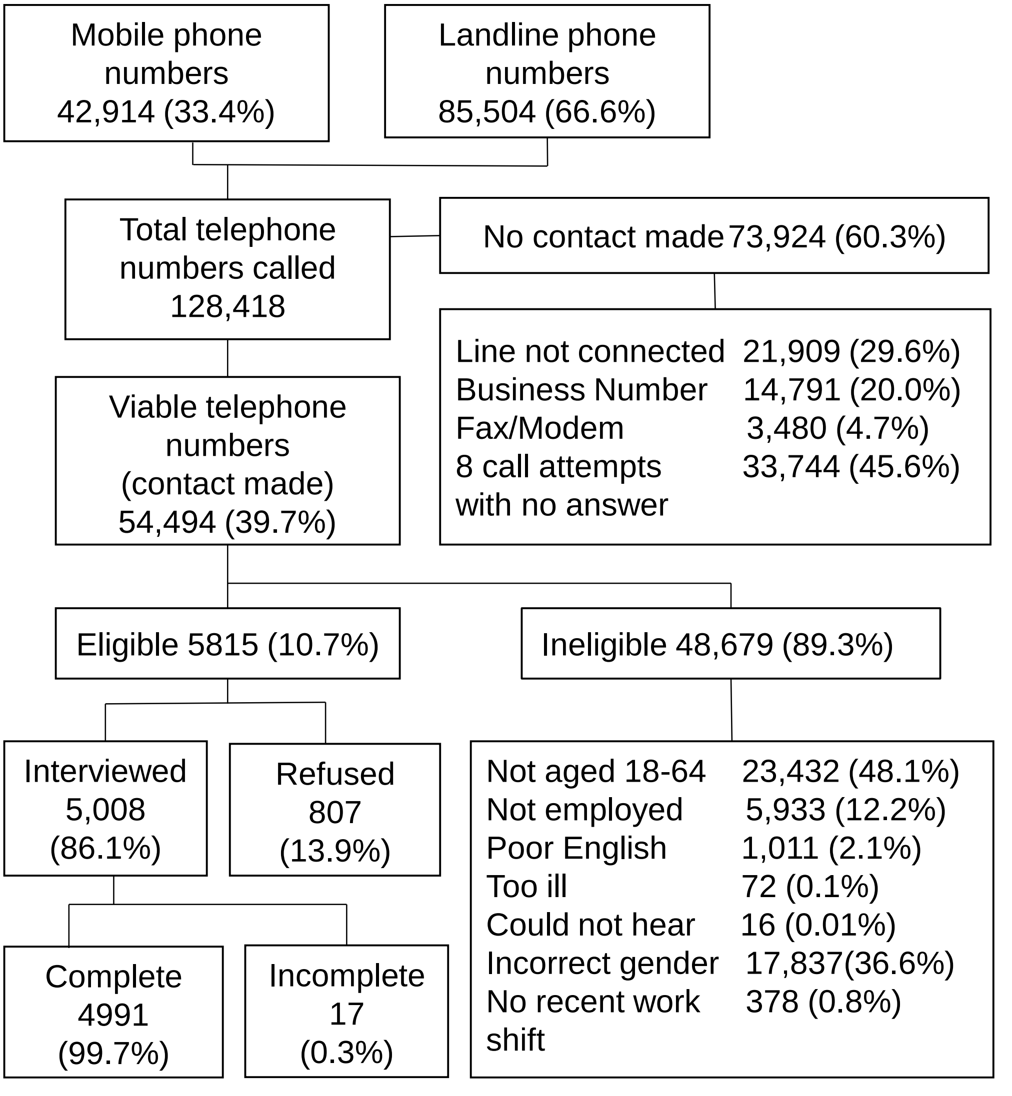
Table 3. Estimated percent of occupational groups within the male Australian working population who are exposed to probable medium or high levels of the ototoxic chemicals with or without co-exposure to noise above 85dB on their last working day

Occupational group	Any ototoxic		Toluene		p-xylene		Ethyl benzene		n-hexane		TCE*		Styrene		CO		Lead	
	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N	Exp	Exp +N
Office	26.8	0.5	2.6						1.2				1.8		26.8	0.5		
IT & engineering	32.6	3.7	5.9	1.6	1.7	0.1	0.6		2.4	0.6	0.3	0.2	3.1	1.1	32.0	3.4	1.6	0.1
Managers	56.1	9.1	15.4	6.9	3.4	2.6	0.5	0.5	4.2	2.4	0.5		4.1	1.1	54.3	7.6	2.2	2.2
Professionals	33.7	0.2	1.1	0.2	0.2		0.2		1.3				1.3		33.2	0.2	0.2	
Education	15.8	1.3	6.8	1.3	2.1				2.1						11.0	1.3		
Farming	93.5	34.8	61.2	23.6	14.0	5.1	4.8	1.0	20.2	7.7	0.9	0.2	18.0	8.7	91.6	32.9	6.0	3.0
Hospitality	41.5	2.7	3.8	0.9	1.5		0.8		2.2				2.6		40.9	2.7		
Retail	38.0	1.1	7.8	1.1					0.2				3.2	1.1	33.2	1.1		
Personal service	54.0	10.1	20.2	6.5	2.2	2.2			2.2	2.2	1.1		7.0	4.6	47.9	10.1	5.7	3.5
Construction	86.4	41.7	64.4	35.2	11.7	6.0	1.2	0.4	11.9	6.1			13.9	5.6	74.3	34.1	7.2	3.8
Drivers	86.1	15.6	16.4	3.4	3.1	1.0	0.4		4.0	1.0	1.0	1.0	5.5	1.5	84.1	15.6	1.0	1.0
Automotive	89.0	57.7	65.9	41.9	35.4	23.4	12.8	10.8	48.0	34.2	5.4	3.7	53.4	36.5	81.4	54.3	29.9	19.4
Other trades	89.5	21.9	48.7	17.7	17.5	8.2	5.7	3.4	12.8	6.9	1.6		11.9	4.5	82.1	18.2	16.0	5.9
Machine operators	64.9	45.7	31.3	21.2	7.4	6.4	1.7	1.7	4.9	3.9			14.2	9.5	61.5	42.2	6.1	6.1
Health	41.1	0.9	0.9												40.4	0.9		

*TCE = trichloroethylene

Exp, Exposed to ototoxic agent; Exp + N, co-exposed to ototoxic agent and noise ($L_{Aeq,8h}$ > 85dBA)

Blank cells denote no exposed subjects.


Mobile phone numbers 42,914 (33.4%)
Landline phone numbers 85,504 (66.6%)
Total telephone numbers called 128,418
No contact made 73,924 (60.3%)
Line not connected 21,909 (29.6%)
Business Number 14,791 (20.0%)
Fax/Modem 3,480 (4.7%)
8 call attempts with no answer 33,744 (45.6%)
Viable telephone numbers (contact made) 54,494 (39.7%)
Eligible 5815 (10.7%)
Ineligible 48,679 (89.3%)
Interviewed 5,008 (86.1%)
Refused 807 (13.9%)
Not aged 18-64 23,432 (48.1%)
Not employed 5,933 (12.2%)
Poor English 1,011 (2.1%)
Too ill 72 (0.1%)
Could not hear 16 (0.01%)
Incorrect gender 17,837(36.6%)
No recent work shift 378 (0.8%)
Complete 4991 (99.7%)
Incomplete 17 (0.3%)