Developing a General Population Job-Exposure Matrix in the Absence of Sufficient Exposure Monitoring Data

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In New Zealand, there is a need for a comprehensive and accessible database with national occupational exposure information, such as a general population job-exposure matrix (GPJEM). However, few New Zealand-specific exposure data exist that could be used to construct such a GPJEM. Here, we present the methods used to develop a GPJEM for New Zealand (NZJEM), by combining GPJEMs from other countries with New Zealand-specific exposure information, using wood dust as an example to illustrate this process. The assessments of GPJEMs from other countries were made available to a New Zealand expert in occupational wood dust exposure, who then provided a preliminary NZJEM assessment (including the percentage exposed and the level of exposure for each occupation). Where possible, this assessment was based on New Zealand exposure measurements. In the next step, information from a nationwide workplace exposure survey of 3000 members of the New Zealand workforce was used to finalize the NZJEM assessments. The final NZJEM listed 104 of the 956 New Zealand occupational codes as exposed to wood dust. The percentage of workers exposed within an occupation ranged from 5% (e.g. boiler attendants) to 100% (e.g. cabinet makers). The level of exposure ranged from 0.05 mg m\(^{-3}\) (e.g. electricians) to 3 mg m\(^{-3}\) (e.g. carpenters). Of these assessments, 23% were mainly based on New Zealand exposure data, 37% on overseas GPJEMs and exposure data, and for 40% the national survey data served as the main source of information for the expert assessment. Combining the NZJEM assessments with national employment statistics indicated that 5.6% of the New Zealand workforce is occupationally exposed to wood dust, corresponding to a total of 97 000 workers (86% male and 14% female). Construction-related occupations included the largest number of exposed workers.

Keywords: expert assessment; job-exposure matrix; wood dust; workforce survey

INTRODUCTION

A general population job-exposure matrix (GPJEM) is a cross-classification of occupations (jobs) and exposures (Checkoway et al., 2004). In epidemiology, the main purpose of a GPJEM is the retrospective assessment of occupational exposure of study subjects, based on their recorded occupations, although GPJEMs can also more broadly function as an information tool for exposure assessment data for a wide range of occupations and exposures.

Kromhout and Vermeulen (2001) presented an overview of the GPJEMs that have been developed since...
of the wood dust NZJEM, these included FINJEM, MRCJEM, and CEEJEM.

**FINJEM.** FINJEM is a multipurpose exposure information system developed by the Finnish Institute of Occupational Health (FIOH). Occupations cover 311 classes of the Finnish Census classification (Kauppinen *et al.*, 1998). The prevalence of exposure (0–100%) and the quantitative mean level of exposure are available (Kauppinen *et al.*, 1998).

**MRCJEM.** MRCJEM is a JEM developed in the Medical Research Council’s Environmental Epidemiology Unit in Southampton, UK. This British JEM was based on cross-tabulated combinations of industrial and occupational classes. Occupations cover 211 classes of the Office of Population Censuses and Surveys 1966 classification (OPCS, 1966), and industries cover the 248 classes of the UK SIC 68 classification (Standard Industry Classification) (Pannett *et al.*, 1985).

**CEEJEM.** This JEM is entirely based on case-by-case expert assessments conducted for a lung cancer case–control study in Central and Eastern Europe (CEE) and coordinated by the International Agency for Research on Cancer (IARC) (Mannetje *et al.*, 2003). Local expert teams evaluated the exposures of the jobs of ∼3000 cases and 3000 controls. The case-by-case evaluations were used to make a JEM using the ISCO 68 (ILO, 1981) codes in the job axis. For each ISCO 68 code, the percentage exposed was calculated, as well as the average level of exposure for the exposed within that job. In order to have sufficient number of assessments within each occupation, all jobs of all cases and controls were included (the 6000 cases and controls had three to four jobs on average) (Mannetje *et al.*, 2003).

**Step 2. Recoding occupational classifications used in GPJEM into NZSCO**

For the job axis of NZJEM, the 1999 New Zealand Standard Classification of Occupations (NZSCO) was used (Statistics New Zealand, 2001), thus enabling direct linkage to New Zealand labour statistics. NZSCO 1999 is a hierarchical classification scheme, based on ISCO 88 (The University of Warwick, 2002) 2002, including a total of 956 occupational codes (562 five-digit, 261 four-digit, 99 three-digit, 25 two-digit, and 9 one-digit codes). The occupation classifications used in FINJEM, MRCJEM, and CEEJEM were recoded to NZSCO codes through one-way coding, i.e. each NZSCO code was linked to the most applicable GPJEM code. A comparability rating was included for each NZSCO code, classifying a ‘good fit’ if the NZSCO job was very similar to the GPJEM job, but classifying an ‘average fit’ or ‘bad fit’ if this...
was not the case. The fractions of occupational titles with a good, average, and bad fit with NZSCO was 59, 37, and 4%, respectively, for FINJEM, 52, 37, and 11% for MRCJEM, and 81, 19, and 0% for CEEJEM, thus indicating that the occupational classification of CEEJEM was most similar to that used for NZJEM. A ‘bad fit’ is illustrated by the example of ‘saw doctor’, which was matched up to the FINJEM occupation ‘assemblers and other machine and metal-ware occupations’ and the MRCJEM occupation of ‘metal plate workers, riveters’, while the CEEJEM occupation ‘saw repairers and sharpeners’ provided a good fit.

Step 3. Construction of ACCESS database for use by the expert

An ACCESS database was developed which linked FINJEM, MRCJEM, and CEEJEM by NZSCO code. ACCESS form-views were developed that enabled the simultaneous consultation of the three GPJEMs for use during the NZJEM expert evaluation. Also, directly available on screen were the definition of exposure, a link to an electronic version of the full NZSCO classification book (2001), the number of people employed in each NZSCO job and the male/female distribution from the 1996 New Zealand Census of Population and Dwellings. In the same form-view, the NZJEM assessment could be entered, consisting of the following fields for each NZSCO code:

- Exposure present: recorded as either ‘yes’, ‘no’, or ‘depends on industry’. Exposure was recorded as yes or depends on industry if at least 5% of the workers within the NZSCO code were considered exposed. If the exposure within the specific occupation heavily depended on the industry in which the job was performed, the industries in which the exposure occurred could be specified. For this industry axis of the NZJEM, the ANZSIC classification was used (the Australian and New Zealand Standard Industrial Classification 1993) (Statistics New Zealand, 1997).

- Percentage exposed: if the exposure was deemed present, the percentage of workers exposed within the job was estimated (5–100%). Exposure was only deemed present if ≥5% of the workers within an occupation were exposed above background levels.

- Exposure level: if the exposure was deemed present above background, the 8-h average exposure level for the exposed percentage within the job was estimated. For wood dust, this was expressed as milligrams per cubic metre inhalable dust.

- Source of exposure: if the exposure was deemed present, the source of exposure (e.g. during what tasks, during use of which products) could be specified in a text field.

- Exposure information: if the exposure was deemed present, the main sources of information that were used by the expert to reach this assessment could be specified in a text field (e.g. the assessment was mainly based on other GPJEMs, overseas exposure data, New Zealand exposure data, or New Zealand survey data).

- Time periods: if exposure had changed dramatically over time, due to changes in for example regulation or production processes, this could be specified by giving separate assessments for different time periods.

- Type of wood dust: if the exposure was deemed present, the type of wood dust (hard wood/soft wood/both) mainly handled in the job could also be specified.

The expert could make use of different form-views of the data, including a view that showed all NZSCO codes and their evaluations in one screen, which could be sorted by any of the above variables, allowing easy comparisons of assessments between jobs in order to improve internal consistency of the NZJEM assessments.

Step 4. Evaluation by expert, resulting in preliminary NZJEM assessments

Preliminary assessments of the percentage exposed and level of exposure for each occupation by the expert were based on New Zealand-specific exposure data where possible and the GPJEMs. The expert had access to New Zealand-specific exposure surveys from the scientific as well as grey literature, through the expert’s own work as an industrial hygienist as well as the expert’s contacts with other professionals in the field. Assessments were made for all four- and five-digit codes of NZSCO. For the three-, two-, and one-digit codes, the percentages exposed and exposure levels were then calculated using the prevalence of exposure and number of workers in each four- and five-digit NZSCO code.

Step 5. Adjusting of NZJEM assessments by using NZ survey data

After the NZJEM assessments for all NZSCO codes were completed, national survey data on self-reported exposure to wood dust were made available to the expert. During 2004–2006, we conducted a telephone survey in a random sample of the New Zealand workforce, aged 20–64 years, collecting information
on work practices, and self-reported exposures. The study methodology is described in detail elsewhere (Eng et al., 2010; Mannelje et al., 2011). Briefly, for the current or most recent job, self-reported exposure to wood dust (among other exposures) was collected using a structured questionnaire. For each occupation of NZSCO 1999, the prevalence of self-reported exposure to wood dust was calculated. This could not be done for all NZSCO codes: of the 562 five-digit NZSCO codes, there were no survey respondents for 36% and only 11% contained >10 respondents (four-digit codes: 19 and 28%; three-digit codes: 9 and 56%). The survey data were presented to the expert as a percentage (% within the NZSCO occupation reported to be exposed to wood dust), as well as the number of respondents on which this percentage estimate was based.

**Step 6. Final evaluation by expert**

The expert then revised the NZJEM assessments by comparing them with the survey data, using their judgement to make any changes and resulting in a final NZJEM assessment.

**Step 7. Finalization of multipurpose NZJEM database**

A final ACCESS database was then constructed to provide easy access to the NZJEM, including easy search and tabulation options, background information such as the numbers of workers in each NZSCO occupation, estimates of the absolute numbers of workers exposed based on NZJEM assessments, the definition of exposure, and national standards for occupational exposure limits.

**Comparisons between GPJEMs, national survey data, and NZJEM**

Cohen’s kappa statistics were calculated to evaluate the agreement between NZJEM and the three GPJEMs as well as the survey data. The kappa statistics were calculated for the presence of exposure (yes/no) over all NZSCO codes \((n = 956)\), with an NZSCO code defined as exposed if at least 5% of the workers within the NZSCO code were considered exposed. Both the preliminary and the final NZJEM assessments were compared with the three available ‘overseas’ GPJEMs and the survey data.

**RESULTS**

The final NZJEM listed 104 of the 956 NZSCO codes as exposed to wood dust (4 one-digit codes, 8 two-digit codes, 17 three-digit codes, 27 four-digit codes, and 48 five-digit codes). Table 1 lists all three-digit occupational groups that were evaluated as exposed in the final NZJEM. The percentage of workers exposed ranged between 5% (e.g. 81612-boiler attendant) and 100% (e.g. 74211-cabinet maker). The level of exposure ranged from 0.05 mg m\(^{-3}\) (e.g. 7131-electricians) to 3 mg m\(^{-3}\) (e.g. 71121-carpenter and/or joiner). The construction-related occupations represented the largest group of wood dust-exposed workers.

Table 2 shows that the GPJEMs differed considerably in terms of the number of occupations (NZSCO codes) they considered exposed, with FINJEM being much less likely to consider a job as exposed compared with MRCJEM and CEEJEM. It should however be noted that FINJEM used 0.1 mg m\(^{-3}\) annual mean level as a minimum criterion of exposure, thereby excluding occupations with temporary, part-time, and low exposure to wood dust. The survey data provided the highest number of NZSCO codes that were considered as exposed. Before the expert had access to the national survey data, the preliminary NZJEM assessments showed reasonable agreement with the three GPJEM, with kappa’s ranging between 0.45 and 0.56. These kappa’s did not change appreciably when only including NZSCO codes for which the fit with the occupational classification of the GPJEM was good (results not shown). The agreement of the preliminary NZJEM assessments with the national survey data was poor (kappa = 0.23). After the expert had received access to the survey data, the expert considered an additional 50 NZSCO codes as exposed. Typically, these represented more general occupations for which, from the title and description, it was not directly obvious they could entail exposure to wood dust but for which the survey data clearly indicated that wood dust exposure was common. Examples included ‘structural engineer’, ‘production manager’, ‘plumber’, ‘painter’, and ‘electrician’. For another 78 NZSCO codes, the survey had indicated that >5% were exposed to wood dust, but for these occupations, wood dust was not considered a structural exposure by the expert. As a result, the agreement with the national survey data increased to kappa = 0.56, while the agreement between the final NZJEM assessments and the GPJEM dropped to kappa = 0.32–0.43.

This is also reflected in the sources of information the expert reported to have used for the final NZJEM assessments. In total, 40% of all five-digit NZSCO codes evaluated as exposed in the final NZJEM assessments were primarily based on the survey data Table 3. For a relatively small percentage of exposed NZSCO codes (23%), the NZJEM estimates could be based on actual exposure measurements performed in New Zealand, including sawmill workers, carpenters, boiler attendants,
and wood products machine operators. The rest (37%) of the exposed NZJEM assessments were mainly based on ‘overseas’ exposure data and the available GPJEMs.

Combining the final NZJEM assessments (percentage exposed in each job) with national employment statistics indicated that an estimated 5.6% of the New Zealand workforce is exposed to wood dust in their workplace, corresponding to a total of 97 000 workers. The wood dust-exposed jobs tended to be male-dominant jobs, and therefore, the actual percentage of wood dust-exposed workers was considerably higher among males (9%) than females (2%). Of the 97 000 exposed workers, 86% were male and 14% female.

**DISCUSSION**

During the development of the NZJEM, we relied heavily on overseas exposure data and overseas GPJEMs, due to the lack of occupational exposure data available in New Zealand. There were two main reasons for this: firstly, New Zealand does not have a strong history of collecting occupational exposure data and; secondly, there has been no effort to centrally store and conserve occupational exposure data. In contrast, some other countries have been able to collect a large amount of occupational exposure data, e.g. in Germany, the MEGA database (Stamm, 2001) is a chemical workplace exposure database of the
Institute for Occupational Safety of the German Berufsgenossenschaften and includes 1 000 000 measurements of >400 substances dating back to 1972. The French COLCHIC database (Vincent and Jeandel, 2001) includes 400 000 measurements of 600 substances collected over a period of 10 years. Although such data cannot directly be used to construct a general population JEM (e.g. measurements having a focus on highly exposed occupations and often being short-term measurements of peak exposures), they are a valuable source of occupational exposure data typically not available for New Zealand. For the wood dust NZJEM, the estimates of only 23% of all exposed occupations were based on actual exposure measurements conducted in New Zealand workplaces, an estimated total of only 200–300 individual measurements. For most other occupational exposures, it is likely that considerably less exposure measurement data will be retrievable.

Using the NZJEM, it was estimated that 5.6% of the New Zealand workforce is exposed to wood dust in their workplace, corresponding to a total of 97 000 workers. This is a higher percentage than that estimated for the European working population (2%) (Kauppinen et al., 2006), which in part be due to the fact that the timber industry is an important production sector in New Zealand. It may however also be due to the use of the national workforce survey data in the development of NZJEM.

The use of the survey data increased the sensitivity of NZJEM by including an additional 50 occupations as exposed, while largely leaving the ‘exposed jobs’ of the preliminary NZJEM assessments unchanged. The additional 50 occupations were generally not considered exposed by the other GPJEMs and were by and large occupations for which wood dust exposure may be specific to the New Zealand situation. These occupations included, for example, structural engineer, plumber, painter, and electrician, in which wood dust exposure is common because the majority of New Zealand houses are made of wood (in contrast to brick houses in e.g. Europe). They also represent occupations with temporary, part-time, and generally low level of exposure to wood dust. The survey data were not sufficient to form the only information source to the expert because: (i) occupations that are relatively rare in the population are not covered; (ii) self-reported exposure to common agents such as wood dust are likely to be over-estimated (Teschke et al., 2002); (iii) it does not give any information about levels of exposure. In addition, because the survey collected information on self-reported exposures, the survey data are not likely to be equally valuable for exposures that are generally not known to be present in the work environment or are not recognized by survey respondents the way wood dust is. Self-reported exposure data therefore will need to be reviewed by an expert before the data can be used in GPJEM. Access to workforce survey data will be particularly useful for widely present occupational exposures, such as wood dust, while being less useful for exposures with only very specific applications.

The other GPJEMs were considered a very useful starting point for NZJEM by the expert, even though ultimately the agreement with the final NZJEM assessments was low. The main advantage of having other GPJEMs available during the first NZJEM evaluation was that they give a complete overview of all occupations while the expert generally does not have experience or knowledge of exposure levels for all possible occupations. Access to these GPJEMs provided a structural means to think about exposures in all possible jobs and illustrated that other GPJEM often disagreed among themselves, which in some cases may indicate real differences in working circumstances in different countries or differences in how the GPJEMs were developed. For example, FINJEM was largely based on measurement data with a relatively high threshold for considering a job exposed, making this GPJEM particularly appropriate to identify highly exposed groups. MRCJEM, CEEJEM, and the final version of NZJEM are relatively more sensitive, considering more occupations exposed, and therefore appropriate to use if the purpose is to quantify the total number of workers with exposure to wood dust, including those occupations with low exposure level and prevalence.

The NZJEM is a work in progress and will contain features enabling it to be updated when new information becomes available. The features that can be updated include:

- Exposure data: if new exposure data become available, references to the data can be added, the NZJEM assessment can be changed, and the anonymized exposure data will be stored at the Centre for Public Health Research.
- Occupational classifications (i.e. if a new occupational classification is introduced, cross-classifications between the old and new versions of NZSCO will be included).
- Labour statistics: as new labour statistics become available, these will be added to NZJEM, thus reflecting changes in the occupational profile of New Zealand, which may in turn affect the total number of workers exposed.

Exposure data: if new exposure data become available, references to the data can be added, the NZJEM assessment can be changed, and the anonymized exposure data will be stored at the Centre for Public Health Research.
- Logfile: a log file with the changes made and on which date will be included.
- Additional exposures: the same methodology will be used to add additional exposures to NZJEM, including chemical, biological, and physical exposures.

**CONCLUSIONS**

Although very few occupational exposure data are publicly available in New Zealand, the combination of overseas GPJEMs, national exposure survey data, and expert assessment has enabled the development of a JEM tailor-made for the New Zealand situation. The methodology for creating a New Zealand-specific GPJEM described here was feasible and practical and could equally be applied in other countries. It has resulted in a multipurpose information system that can be used in New Zealand based epidemiological studies, as well as functioning as an information source for policy makers and other occupational health professionals.

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