A field evaluation of techniques used to construct a quantitative job exposure matrix

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Introduction

A quantitative job exposure matrix (JEM) was created for historical exposures to a number of chemicals, including beryllium, at a U.S. Department of Energy (DOE) site. Monitoring data were limited or non-existent for many jobs and exposures, and much of the JEM was completed by using qualitative information obtained from employee interviews, and published data for similar operations and tasks from industry or other DOE sites. Since all available data had been used in estimating exposures, the estimates could not be directly validated at the DOE site. Instead, these techniques were evaluated by constructing a similar beryllium JEM at a separate industrial site (plant A, which also machined beryllium), and comparing the estimates to an independent set of beryllium measurement data, withheld from the estimation process, collected in 1996 and 1997 at plant A.

Methods

At Plant A, a small team of occupational health professionals, led by an experienced industrial hygienist, formed job groups and estimated exposures to beryllium, blinded to the 1996/97 monitoring data. Ten collapsed jobs were initially ranked based on employee interview information. A limited monitoring data set (n = 42) generated by plant personnel in the mid-1980s was used to develop initial estimates of exposure, similar to what was done at the DOE site. Published monitoring data from other beryllium plants were reviewed and applied, adjusting for frequency and duration of exposures, and differences in processes, equipment, and controls. Additional final adjustments to the estimates were made for several process and control changes between the mid-1980's and 1996/97 at Plant A (e.g., removal of air pressure hoses). These were judged to collectively reduce exposures by about 20%. Once the estimates were complete for each of ten collapsed jobs, they were paired with the geometric mean for the same job calculated from the 1996/97 data and statistically analyzed.

Results

Table 1. Beryllium exposure estimates (µg/m^3) and monitored geometric means.

Rank	Job/Task	Estimated Exposure	Measured GM (N)
1	Grinding	1.6	0.65 (35)
2	Deburr	0.96	1.41 (45)
3	Lathe	0.64	0.64 (15)
4	Milling	0.60	0.35 (39)
5	NC Mill	0.48	0.17 (9)
6	Lapping	0.25	0.20 (39)
7	Maintenance	0.1	0.16 (1)
8*	Inspection, Tooling, & Assembly	0.01	0.015 (6)

* Three unmonitored jobs assumed unexposed; Plant A ambient background measurements were used for comparison.

Table 1 lists each job in descending order of the estimated exposure. The bias between the two paired sets was 0.10 µg/m^3 (Estimate – GM), the precision was 0.36 µg/m^3, and the total accuracy was 0.37 µg/m^3, about 103% of the mean concentration of 0.36 µg/m^3 in the ten collapsed jobs. Figure 1 displays the1996/97 independent beryllium monitoring data for the collapsed jobs, from which the geometric means were calculated. The high-range data points in the deburr and grinding job groups suggest that non-homogenous tasks have been combined. It was not possible, after the fact, to exclude these points or divide the job into two or more different job groupings for the purpose of the paired comparison, since the estimates had been made for all tasks within the deburr and grinding jobs.

A moderately strong relationship (Pearson's R = 0.73; p = 0.017) exists between the estimates and the geometric means of the 1996/97 data (Figure 2). The intercept of the regression line is near zero (0.075, p=0.62). The calculated slope is less than the expected value of 1 but not significantly less (0.60, p = 0.10). The grinding job had a larger than average influence on the regression (leverage of 0.64; and a studentized residual of -3.1, more than three times the average value). Removal of this point improved the results considerably (R = 0.89, intercept = -0.064, and slope = 1.16). Using all ten pairs, a paired t-test (p = 0.39), a sign test (p = 0.75), and a signed ranks test (p = 0.84), all indicate no significant differences on the average between the paired values of estimated exposure and geometric mean exposure. Spearman's rank correlation coefficient (0.98, p = 0.0003) also indicated relatively accurate comparative rankings.

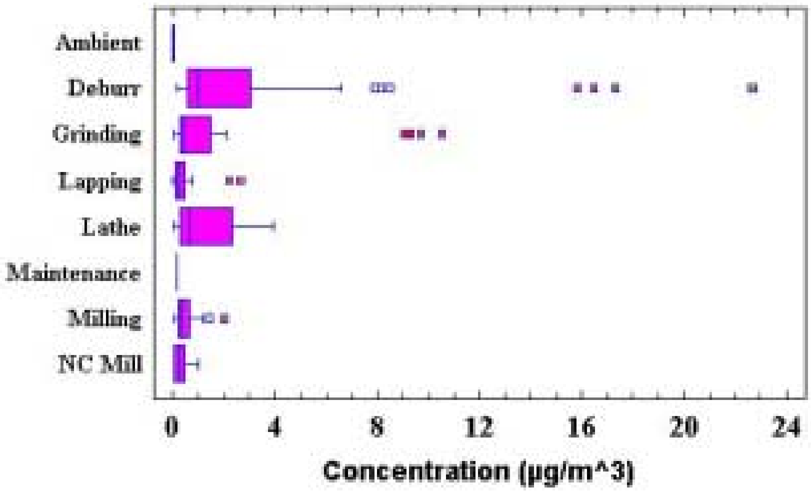

Figure 1. Box-whisker plot of 1996-97 data (N = 189). The central box shows the interquartile range (25th-75th percentile), the vertical line within the box shows the median, and the whiskers extend to 1.5 times the interquartile range. Points marked with + are >3 times the interquartile range. There four such points for deburr, and six for grinding.

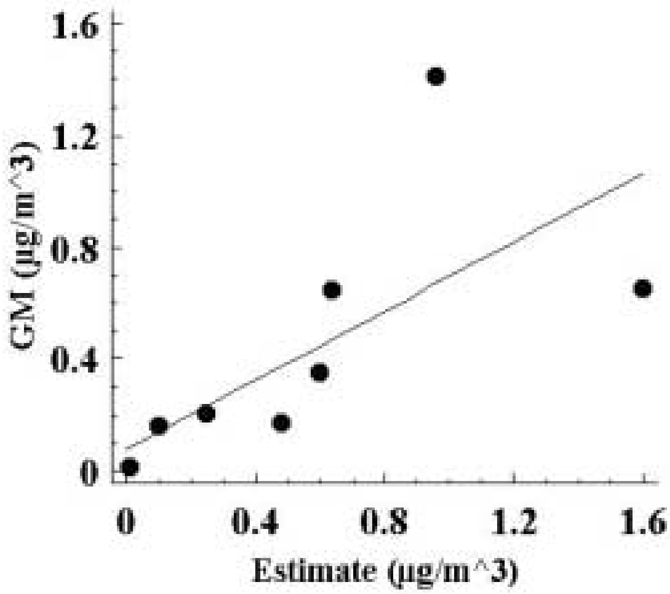

Figure 2. Scatter plot of ten values from Table 1, and linear least squares regression.

Discussion

The job rankings obtained at Plant A in this evaluation (Table 1) were not identical. In particular, two pairs of closely ranked jobs (grinding vs. deburr, and NC Mill vs. lapping) were reversed compared with actual geometric mean exposures. However, in general, the overall placements were surprisingly good, meaning that highly ranked jobs had the highest estimates, and the lowest ranked jobs had the lowest estimates. In addition, the exposure estimates were very similar to the measured exposures.

Conclusions

The results of this study suggest that acceptable estimates of exposure may be obtained through interviews with knowledgeable workers, by carefully applying published quantitative exposure monitoring data, and using that information with careful adjustments for known determinants of exposure in the workplace. The results further suggest that the JEM estimates for the DOE-site, which used the same techniques for several different chemical exposures, are reasonable. Extensive knowledge of processes, conditions, and determinants of exposure, gained primarily from employee interviews, coupled with published literature values where this information is also well documented, are important for valid application of these techniques.

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Preface

This book contains the extended abstracts to the X2001 Conference on Exposure Assessment in Epidemiology and Practice in Göteborg, Sweden, June 10-13, 2001. The excellent work performed by the contributing scientists has made this book a first-class, up-to-date, state of the art review on what is known about exposure assessment today.

The outstanding scientific quality of the extended abstracts was secured through the work of five international programme committees. The chairmen for the committees were: Chemical, Patricia Stewart; Ergonomic, Alex Burdorf; Physical, Ulf Bergqvist; Psychosocial, Annika Härenstam and Biological, Jean-Francois Caillard.

Financial support to the conference and thereby to the publishing of this book was made possible by contributions from The National Institute for Working Life, Stockholm, Sweden; The Swedish Council for Working Life and Social Research, Stockholm and Volvo. Without the excellent skills of the organizing committee - Ulrika Agby (administration and layout), Ann-Sofie Liljenskog Hill (administration) and Christina Lindström Svensson (administration) - the production of this book would not have been possible.

We want to express our gratitude to the contributing authors, session chairmen and to the participants who presented papers and contributed in the discussions, for making X2001 an outstanding meeting.

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