המוסד לבטיחות ולגיהות
בטיחות ובריאות בעבודה - זה אנחנו.

Extended Abstract

Introduction

Several approaches for occupational exposure assessment exist, the majority of which involve qualitative/semi-quantitative or quantitative assessment. Qualitative or semi-quantitative assessment is based on various factors, mostly descriptive, and the potential exposure level may be rated on an ordinal scale (low, medium, high), since at this stage quantitative exposure measurements are usually lacking. This type of assessment usually employs a walkthrough survey at the work site. In comparison to qualitqtive assessment, quantitative assessment relies on measurements and therefore is more accurate and specific; however, environmental monitoring is carried out only periodically and the results are dependent on the conditions prevailing at the time of sampling. Hence, the probability of erroneous assessment may be significant when a correlation is sought between a semi-quantitative assessment and monitoring results.

Different assessment approaches and statistical models have been developed in recent decades to enhance accuracy and reliability of such correlations. Industrial hygienists have developed strategies of exposure assessment, using technological processes in a workplace as a basic unit for forming the similar exposure groups (SEG) which constitute a central element in standard exposure assessment methodology. However, characterizing the exposure of a work force has encountered difficulties when the work force has been classified by technological processes and jobs only. These difficulties have led professionals to recommend that SEG classification and exposure assessment also include characterization of work tasks. Breaking the process into its tasks and conducting a task-based exposure assessment help to refine the exposure characterization and reduce both misclassification of SEGs and assessment errors. Another benefit of task-based exposure assessment is the lower likelihood of masking exposure peaks when assessing time-weighted average exposure over long processes or over workshifts. Recently, studies have indicated that task-based exposure assessment is not always an advantageous strategy and that the correlation between assessment by this strategy and assessment by process-based strategy is not always satisfactory. There is a need to combine the two approaches case by case, in accord with job type and exposure scenario.

The use of probabilistic exposure matrices has been recommended to deal with the challenge of more complex exposure scenarios and their health risk assessments. From the relative contributions of each component in the matrix and of the interactions between them can be derived a weighted outcome, defined as an exposure rank. The methodology of exposure matrix analysis is widely used and has been proved efficient in assessing occupational health hazards.

Maintenance of motorized vehicles in auto repair garages was selected in the present study as an industrial category suitable for exposure assessment through the use of exposure matrices. The aim of this study was to construct exposure matrices allowing the ranking of exposure estimates for hazards present in such garages under given work pattern and exposure conditions. The study examines a control tool aimed at separating a work process into its component tasks and analyzing the exposure for each task so as to reduce the possibility of failing to detect short exposure excursions. Another goal of this study was to develop computer software that could construct exposure matrices based on a model.

Research Methods

The study included 50 garages, 35 civilian and 15 military (workshops), located in the north, center (including the region of Jerusalem) and south of the country. Data gathered by the Ministry of Industry, Commerce and Labor in recent years through environmental surveys and monitoring served as the basis for classifying working processes in garages. For each garage, the work processes and tasks were categorized, and the characteristics of the processes and tasks as well as those of the relevant exposure variables were surveyed. The most common categories of processes were chosen in order to attain enough observations for hypothesis testing. A structured questionnaire was used to gather garage survey data about work processes and tasks. Detailed data were obtained by observations at the garage and from information supplied by garage owners and workers. Once specific work processes had been identified, each was broken down into a series of tasks. Data were gathered separately for each process as a whole and for each task in that process as to duration, frequency, work procedure and conditions of exposure, chemical hazards present, the quantity of the chemical agent present during performance of the process or task, and the form in which the agent appeared in the air during exposure. Data were also collected as to the engineering, managerial and personal controls in place for each process and task. These comprised the independent variables in the study. Each variable was represented in the questionnaire by a multiple choice question. In each variable, the appropriate response option was selected by the surveyor to best describe a given exposure scenario in a garage. Each option selected was given a qualitative numerical score ranking its relative contributing weight to the potential exposure on a qualitative scale. Each score was then normalized to the maximum score given in that variable category. The exposure variables were divided into three clusters, and the combined ranking of each was constructed by weighting the relative contributions of its variables and the interaction between them. The scores of the three clusters were combined using a model-derived formula to yield one general score reflecting a potential exposure rank. The combination of all given exposure variables in a given exposure scenario was defined as an exposure matrix and the potential exposure general score calculated for this scenario was assigned to that exposure matrix.

A graphic model was developed where the three weighted scores of the three clusters were plotted as points on orthogonal axes, creating a right-angled tetrahedron.

Connecting the three points formed a triangle of calculable area in the space within the tetrahedron. The surface area of this triangle represented an exposure matrix with a qualitative potential exposure rank. The maximal possible surface area among all the possible combinations of the exposure variables served as a reference maximal score to which the score estimates of the exposure matrices were compared. The maximal surface area was further divided into three sub zones each defining an exposure rank: low (estimating potential exposure up to 50% of the Occupational Exposure Limit (OEL)), medium (estimating potential exposure between 50% of the OEL and the OEL), high (above the OEL).

Air sampling was performed for every process and task to assess the level of exposure to chemical hazard factors. All methods of assessment used were based on those approved by the supervision department of the Ministry of Industry, Commerce, and Labor. The exposure levels obtained were calculated as exposure doses: the time weighted average exposure level (TLV-TWA) was used as a reference value to calculate the exposure dose in each process, and the short term exposure level (TLV-STEL) or three times the TLV-TWA (for excursions in the absence of STELs) was used to calculate brief exposure doses in tasks.

Descriptive statistics were calculated for the exposure dose of each process and task.

Exposure profile probability plots (EPPP) were drawn for each to depict the exposure levels on probability paper as a function of the cumulative probability of their appearance. These plots indicated the cut-off points for recommending whether process or task should be the appropriate unit for exposure assessment in a given exposure scenario.

Including the results of the environmental monitoring in the construction of the exposure matrix allowed estimation of a given level of respiratory exposure for a given case as a function of the exposure characteristics and factors in that case.

In order to obtain a predictive correlation between the results of the potential exposure matrix model and observed respiratory exposure, the exposure matrices thus derived were compared to corresponding findings of monitoring, and the degree of fit between the two was calculated. In order to allow accessibility of the exposure matrix model for potential users, a WEB application program for these calculations was developed, to be available over the internet.

Results

Classification of processes in auto repair garages created five major categories and a sixth, infrequently performed process characteristic of military garages only. Mechanics was the most common process, and it was more frequent in civilian than in military garages. Painting was the second most common process. Equal frequencies were found for processes of metalworking and puncture repair while the latter was more frequent in military than in civilian garages. A full fueling process was observed in two military garages only.

A broad variety of tasks was observed in the processes studied. Mechanics included the most tasks, and the most frequently performed tasks. A broad variety of chemical hazard factors was found. Most prominent were organic solvents and metals, as well as inorganic materials and organic polymers, most having forms of dispersion designated as particulate not otherwise specified (PNOS). Oils and fibrous materials were also found.

The frequency of processes lasting more than four hours per work day was low (12.6% of all observations), and the most frequent duration for a process, as observed, was from 15 to 60 minutes. Most processes were performed daily (66%), and 30% of the observations were of processes performed three to four times weekly. In 70% of the observations a mechanized process manually operated took place. Quantities of materials with potential for airborne dispersion during the various processes were most frequently estimated in the survey as not exceeding 100 grams (around 49% of all observations). Metalworking was most frequently reported to use materials in amounts up to 1 kg and those exceeding one kg. Chemical hazard factors observed appeared in the air in five physical forms: dust, fibers, fumes, droplet aerosols and vapors. Vapors of organic solvents were the most frequently found chemical hazard because these materials were the most frequently used in all five processes observed in the garages. Garages do not usually employ engineering exposure controls, and workers generally use no personal respiratory protection or protective plastic gloves.

The durations of most tasks was found to be notably short, with 70% of them lasting less than 15 minutes. Most tasks in garages (65%) are mechanized-manually operated. The minimal use of ventilation and personal respiratory and skin protection characterize the tasks as it did in the processes.

The dispersion of airborne exposure levels is very broad, with a log-normal distribution pattern. The exposure levels to materials in the processes are usually low. The geometric means of the exposure doses did not exceed any action level for any material. With the exception of metals, none of the unbiased arithmetic means of the exposure doses exceeded the action levels. Differences in exposure level were found between civilian and military garages. Due to the largely right-skewed probability distributions, the unbiased arithmetic means of the exposure doses were higher than their geometric means.

The number of deviations of exposure levels from the TLV for processes in the garages was small, and reached 4.6%. The deviations from the TLV for hazard groups reached 3.5% of the samples analyzed for solvents, 4% for metals and 8% for particles. In the tasks, as well, deviations from the TLV reached only 5%. Deviations were found for solvents in the processes of painting and fueling, for particles in auto body work, and for metals in soldering. Similarly, the exposure profile probability plots (EPPP) are adjacent for monitoring results performed per process and per task, indicating similar behavior in both cases. The EPPP of exposure doses for tasks indicates no task exposure particularly deviant relative to short term exposure limits (TLV-STEL or excursion limits), and hence not masked by time weighted averages obtained over a full process or a shift.

According to the exposure matrix model developed, most potential exposure ranks predicted by the model for the various exposure scenarios in garages belong in the negligible to low exposure zone. The fit between the potential exposure rank as calculated by the model for each scenario and the range of actual monitoring results reached 92%. The model's predictions were higher than the actual exposure range (false positive) for 2.3% of the observations. In 5.6% of the observations the model's predictions were lower than the actual exposure range (false negative). In such cases, decision-making based on the model alone might have resulted in workers having been exposed to levels of hazards beyond the permitted level or at a level of exposure higher than that predicted.

Discussion and conclusions

The present study examined the roles of work process- and task-based exposure assessment and of the optional use of exposure matrices in occupational hygienists' evaluation of occupational exposure in auto repair garages. Breaking workplace activities down into work processes contributes to the recognition of exposure sources and their hazard potential, and to the rating of hazards on a qualitative scale of risk levels. However, in complicated scenarios or multi-task activities, it may be inherently difficult to characterize exposure by classifying the work force according to jobs and processes only. This difficulty has led professionals to recommend a focus on work tasks during qualitative and quantitative exposure assessment. Breaking down a process into tasks helps in assessing peak exposure. In maintenance and service occupations, such as auto repair garages, it is more difficult to compose similar exposure groups for exposure assessment. The parallel or alternative use of processes and tasks as units of analysis, together with the use of exposure profile probability plots (EPPPs) could help in dealing with this difficulty.

In most cases, the general patterns of the EEEPs obtained in this study for a process and its tasks were enough similar to suggest that task-based assessment in these cases had no advantage over process-based assessment for auto repair garages. In a very small number of cases, the exposure level for a task exceeded the TLV, while that for the process was below the TLV-TWA. In these few cases, assessing exposure by process alone would have masked worker exposure above that permitted over some part of the process, and created an underestimation of the actual exposure. In another few cases, the opposite situation occurred, and no excessive exposure for a task hinted at the fact that the process to which the task belonged exceeded the TLV-TWA.

The operational variables comprising the survey of potential exposure and the exposure matrix in garages were selected based on the idea of assessing potential respiratory exposure using a minimum of characteristics (variables). The exposure matrix model used in this study together with the computer software developed are offered as tools for use at the discretion of the industrial hygienist, but are not intended to replace professional judgment or statistical procedures for assessing exposure.

The development of the exposure matrix achieved the capability to predict ranges of actual exposure which correspond to the functional ranges in safety and hygiene regulations. The level of resolution attained in predicting actual exposure level is not sensitive enough to distinguish between narrow bands of exposure level. On the other hand, applying the exposure matrix developed in a pilot studying in given exposure scenarios may identify situations where assessment of potential exposure may underestimate actual exposure in future assessments of such scenarios.

Use of exposure matrices should be encouraged, because they can aid industrial hygienists in assessing potential exposure and improve decision-making reliability in complex situations involving multiple variables. Use of EPPPs provides an analytical tool which can help to determine whether process or task should be the unit of choice for exposure assessment. Although this model could be applicable to other industries, applicability must be verified through survey and monitoring data base gathered for each industry.