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Database Needs for a Task-Based Exposure Assessment Model for Construction

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Construction workers suffer elevated disease and death rates. However, with the exception of lead and asbestos, little exposure data among this population have been documented in the literature. The dynamic nature of construction challenges the occupational hygienist attempting to characterize exposures among respective trades. The site, the sector (commercial, residential, industrial, etc.), the work force (both individual workers and craft combinations), and the materials are ever-changing variables in the construction industry. Construction workers, who are trained in specialized skills, routinely work on different sites with different employers. For the construction worker, skills (or specialized tasks) that are carried from job to job represent the most constant aspect of their work. The feasibility of using a task-based approach to exposure assessment in construction is currently being evaluated by the Center to Protect Workers' Rights. This article presents the preliminary data needs identified by this effort. In its first iteration, this approach is to be piloted for evaluation of chemical exposures. Components of information to be collected are: (1) record keeping, (2) task description, (3) exposure data, (4) sampling/analytical data, (5) bystander data, (6) controls/environmental conditions, and (7) exposure history. Experienced construction workers with special training will assist in collection of data to be included in the task description, control information, and bystander exposure modules. SUSI, P.; SCHNEIDER, S.: DATABASE NEEDS FOR A TASK-BASED EXPOSURE ASSESSMENT MODEL FOR CONSTRUCTION. APPL. OCCUP. ENVIRON. HYG. 10(4):394–399; 1995.

Estimates of the number of workers employed in the construction industry range from 6 million[1] to 7.6 million.[2] A proportionate mortality ratio (PMR) compares the observed death rate from a particular disease in an exposed population with the expected death rate of a similar but unexposed population. A PMR of 100 would indicate no differences in death rates between an exposed and an unexposed group of workers. Among white male construction workers, PMRs are elevated for a number of diseases, including cancer of the nasopharynx (147), pneumoconioses (182), asbestosis (393), silicosis (327), and lung cancer (110).[3] However, little exposure data on occupational exposures of construction workers can be found in the literature.

Attempting to characterize exposures among construction workers is particularly challenging since most of the parameters that determine exposure are perpetually changing. Construction projects involve multiple contractors and their respective craft employees, who enter and exit the job according to project-specific schedules and sector-specific needs. Therefore, both the character of the work and the number of workers generating contaminants are likely to be a unique mixture at any given time on any given project. For instance, a small crew of equipment operators, carpenters, and laborers would constitute the work force in the excavation phase of a new construction project, while hundreds of pipe fitters, electricians, carpenters, and other craftspersons may work side-by-side around the clock during industrial turn-around projects.

The degree of enclosure is also a dynamic parameter in construction. A pipe fitter's welding bench may stand on an open slab at the start of a project and several months later be totally enclosed by newly constructed walls. Finally, because buildings represent architecturally unique structures, the mixture of materials and construction systems used on each job is likely to be different.

The Need for a Task-Based Approach

Contaminant generation is a function of process, task, workers, and materials. Unfortunately, current exposure data often lack descriptive detail for each of these variables. Instead, a particular worker may be sampled over an 8-hour shift, and at the end of the day the job title and the 8-hour time-weighted average (TWA) exposure to a particular agent are recorded. The weakness of this approach is illustrated by looking at asphalt fume exposures among roofers. In 1991 to 1992, the Center to Protect Workers' Rights sponsored a study of health hazards on a new office construction project.[4] A roofing operation that occurred during this study involved four principle tasks: (1) kettle operation, which involved charging a kettle operated at approximately 500°F (260°C) with solid asphalt tubes; (2) filling 5-gallon buckets with hot asphalt and carrying them to mobile mop buckets located throughout the roof; (3) mopping or spreading hot asphalt; and (4) cutting and laying 4-inch thick fiberglass insulation boards onto freshly mopped plywood decking. Workers performing these tasks were monitored for the benzene-soluble fraction of asphalt fumes. Although only eight samples were collected, the results presented in Figure 1 illustrate the variability between task-related exposures. In this case, the roofer who operated the kettle had an exposure three orders of magnitude greater than exposures measured during mopping. This example indicates that the use of occupational classifications alone may blur the true exposure picture of individual workers. This example also demonstrates that task-associated exposures can be useful in setting priorities for interventions. In this case, engineering controls aimed at reducing asphalt fumes generated from kettles would serve to reduce the highest exposures associated with roofing.

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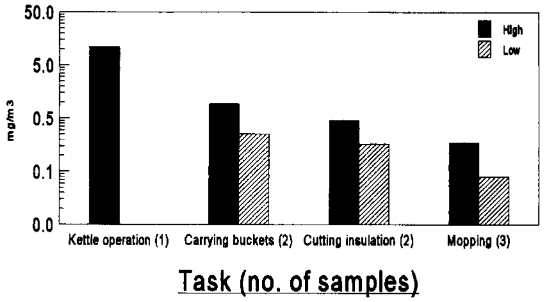

FIGURE 1. Benzene-soluble fraction asphalt fume exposures among roofers by task.

For any given construction worker, the tasks performed may vary within the workday, within the job, and between jobs. Within-day task variability could take one of two forms: (1) intermittent similar tasks of varying duration; or (2) intermittent dissimilar tasks that result in a unique mixture of exposures. Measuring 8-hour TWA exposures in either case would be of very little use for estimating exposures for larger populations of workers or for identifying processes that should be targeted for controls. In addition, very high exposures received over short periods are missed by 8-hour TWA measurements. If dose-rate effects exist for a particular agent, such that brief, high level exposures may have a greater physiological significance than longer, low level exposures, it is important to characterize these brief, high level exposures in terms of both magnitude and duration.

Within-job task variability refers to the day-to-day variability of tasks on a single project. For instance, during the previously referenced new construction project, a plasterer spent several weeks spraying mineral wool insulation. Some months later on the same job, the same plasterer spent several days troweling a cement surface coating onto exterior walls. Capturing the full spectrum of agent-specific exposures a construction worker may encounter from day to day, even on a single project, can be difficult unless on-site workers can assist occupational hygienists in hazard recognition activities. Furthermore, the plasterer described by this example received exposures to respirable quartz at levels in excess of the National Institute for Occupational Safety and Health (NIOSH) relative exposure limit (REL) from a nearby sandblasting operation while surface coating. The sandblaster, who wore a type CE abrasive blasting helmet, was a laborer who worked for a different subcontractor than the plasterer. Such bystander exposures are common in the construction environment, adding to the complexity of characterizing craft-related exposures.

Between-job task variability is used here to describe the variability associated with individual projects. Since construction workers commonly work on multiple projects for multiple employers in any given year, site-related exposures will vary depending on background processes and the materials and systems specific to that site. For example, a pipe fitter working on the new construction project already described welded carbon steel pipe for approximately 6 months. The next project on which this pipe fitter was employed may have been very similar, or it may have involved different base metals and a different welding process.

Given the dynamic nature of this industry, attempts to fully characterize exposures among construction workers must also include collection of information on task-dependent variables, duration and frequency, and bystander or site-specific agents. Using "task" as an independent variable or central organizing principle, descriptive information on other variables that affect exposure can be collected in a systematic way.

As apprentices or through on-the-job experience, all construction tradespeople acquire skills that they will carry with them from job to job and employer to employer. Familiarity with one's trade and the ability to manipulate the tools of that trade are the only claim to job security a construction worker has. It is in this context that a task-based approach has particular appeal, since experienced tradespeople can provide much of the information we need to know about the character, frequency, and duration of specific tasks within individual trades.

Applications of a Task-Based Exposure Database

Occupational hygienists collect exposure data for three purposes: (1) to provide baseline exposure data that will be used by epidemiologists studying the relationship between exposures and health outcomes; (2) for diagnostic purposes such as targeting processes for controls and verifying the effectiveness of implemented controls; and (3) for compliance reasons such as ensuring that a group of employees are not receiving exposures above permissible exposure limits (PELs) enforced by the U.S. Occupational Safety and Health Administration (OSHA).[5]

The development of a task-based exposure database for construction work will find application, either directly or indirectly, in each of the three areas outlined above. The most direct application of task-based exposure data will be in targeting specific tasks for intervention and verifying the efficacy of implemented controls. Using the example of roofers, our task-based exposure data would point to kettle operation as the first target for controls. Using a task-based approach to measure exposures during a simple intervention, such as keeping the kettle lid closed whenever possible and maintaining as much distance as possible between the operator and the kettle, would tell us how effective such an intervention is in reducing exposures associated with that task.

In construction, where many of the terms of work are defined *a priori* through project specifications and contracts between owners and contractors, it is very important that the contractor and owner anticipate potential health hazards and prescribed controls during the prebid phase of construction. This will enable the contractor who plans for worker protection to remain competitive with other bidders. A database of exposures associated with specific tasks, materials, available controls, and other exposure variables will provide the basis for reasonable working assumptions about protective procedures. Such an approach is not intended to preempt exposure monitoring once work begins. This will still be needed to characterize long-term exposures and verify the effectiveness of controls in practice.

The use of task-based exposure data for the purposes of epidemiology is undoubtedly a more complex endeavor. However, the advantage of such an approach can again be demonstrated through our example of roofers. Asphalt fumes have been associated with lung cancer.[6,7] Given this relationship, one of the most important issues to be addressed by epidemiologists is the association between asphalt fume exposure among roofers and lung cancer. Because health insurance and death benefit claims for union roofers are available, it would be possible to study the incidence and the prevalence, respectively, of lung cancer among union roofers.

To sharpen our ability to detect increases in morbidity it is necessary to stratify the larger population of roofers into smaller categories with more narrow and similar exposure ranges. An epidemiological study that is able to isolate the incidence of lung cancer among roofers who spend a considerable amount of their working life engaged in high exposure tasks (such as kettle operation) is likely to have more power to detect increases in lung cancer incidence, given that we would expect to observe a greater level of morbidity among these workers. Because of differences in the carcinogenicity of coal tar pitch and petroleum asphalt, it would also be necessary to document the type of roofing material used for kettle operation.

By building more descriptive databases on the specific tasks performed within a given occupation (including information on relevant task-related variables) and the frequency and duration with which they are performed, epidemiologists will be better able to stratify subpopulations of workers into more similar exposure categories. Work sampling, an industrial engineering procedure aimed at characterizing the frequency and duration of tasks, has been used for the purpose of linking exposures to tasks.[8] In addition, a model for using task-averaged exposure data along with information on task frequency and duration to characterize exposures has also been described.[9] While exposure records in construction are rare, information on task descriptions, frequency, and duration can be compiled by interviewing workers. For example, a veteran pipe fitter could provide an estimate of the percentage of time spent welding carbon steel in an enclosed area versus outdoors, or a painter could estimate the percentage of time spent abrasive blasting with silica sand. Greater information on task-related exposure from discussions with experienced workers may provide the bridge to reconstructing exposure distributions among specific categories of workers.

Finally, task-related exposure data have recently found an application in the compliance arena. Traditionally, the use of controls to protect workers is triggered by monitoring to determine whether or not a worker is exposed to some regulated agent in excess of a designated action level or PEL. The result is that workers may be exposed to harmful exposures during the interim period before exposure monitoring results are available. Although such an approach fails to fully protect workers in all industries, it is particularly problematic in the transient environment of construction, where a job may be over before an occupational hygienist is able to measure exposures and prescribe suitable controls.

The OSHA Interim Lead in Construction standard sets a regulatory precedent in that the standard requires interim controls for specific tasks associated with very high levels of lead exposure.[10] In this standard, certain ranges of presumptive exposures are associated with specific tasks. Personal protection designed to reduce exposures from the presumptive levels to below the PEL must be provided until the employer is able to document through monitoring that exposures are in fact below the presumed levels. The standard does not eliminate the employer's obligation to conduct exposure monitoring; however, it does provide interim protection to workers until exposures have been adequately characterized. If this standard serves as a forerunner to similar OSHA standards, there is clearly a need to build a task-based exposure database that will assist OSHA in the rule-making process.

Task-Based Data Components and Data Collection

In its first iteration, the task-based exposure assessment model (T-BEAM) we propose would focus on chemical hazards and include seven components of information: (1) record keeping; (2) task description; (3) exposure data; (4) sampling/analytical data; (5) bystander data; (6) controls/environmental conditions; and (7) exposure history. Additional fields for general notes and process schematics will also be included. Construction safety and health specialists (CS&HSs), experienced construction workers with training in health hazard identification, will be used to compile task descriptions and bystander and control information. Occupational hygienists will work in concert with CS&HSs, with the latter serving as front-line gatherers of information on potential exposures and task frequency and duration. Occupational hygienists will supervise data gathering and review preliminary information collected by CS&HSs to determine when to follow up with exposure monitoring. Once developed, the T-BEAM could be expanded to include additional components on ergonomics and physical hazards.

The central component around which the rest of the data are linked is the task number. Each task will be assigned a unique number which can then be used to link information on exposure, controls, and all other aspects of the survey. In some cases, a task may involve multiple components, each of which may have unique exposure characteristics. As currently drafted, the T-BEAM would have one field each for a major task and major task number, respectively. Additional fields for task components and task component numbers of the major task will also be included. Figure 2 presents a sample of how the major task of wall demolition would be described by such a model. In this example, there are three distinct task components to the major task of demolition of painted plaster walls.

From a control perspective, stratification of tasks may be required when the major task is judged to be hazardous and task components represent very different magnitudes of exposure. The use of direct reading/real-time instruments will permit characterization of exposures at this level of detail. For instance, the task component 001.01, using a sledge hammer to break up plaster, may have a very high rate of dust generation relative to other task components. By focusing on ways that we can reduce dust generation during this particular activity, overall exposures will be reduced.

A sample of the type of data fields to be completed by occupational hygienists and construction safety and health specialists appears in the Appendix.

Many of the data fields proposed by this model are not new to industrial hygiene surveys. Those that may be unique to construction or a task-based approach are discussed below. It is important that the record-keeping information include information on both the site where work is occurring and the construction sector. Construction workers are employed in wide-ranging sectors, from residential new construction to demolition of industrial facilities. Clearly, many of the chem-

Major Task: Demolition of Painted Plaster Walls
Major Task No.: 001
Major Task Duration (mins): 31

Task Component	TCN	NWT	Tool type(a)	Tool name	Materials	Exposure(b)	TCD (mins)
Breaking up plaster	001.01	2	hand	sledge hammer	------	lead,quartz	20
Shoveling debris into wheelbarrow	001.02	1	hand	shovel	------	"	10
Dumping debris into waste chute	001.03	1	-----	-------	------	"	1

Key: TCN-Task component number
NWT-Number of workers engaged in task
TCD-Task component duration
(a) hand, pneumatic, power
(b) NOHS hazard code: actual exposure and trade name exposure

FIGURE 2. Sample task description.

ical exposures that are encountered will be related to the sector in which they are employed. We also propose that a data field for video/slide set number be included in the task description section. This will enable occupational hygienists to retrieve a more detailed description of the task at a later date, including real-time exposure data, if such could be overlaid onto the videotape.

Discussion

Arriving at standardized data fields for tasks is the most problematic aspect of this model. For example, Table 1 presents task-specific exposure variables for two common construction tasks, welding and cutting concrete. These variables were identified as important task-related data fields by a technical advisory group composed of individuals who are knowledgeable in surveillance strategies, the construction industry, or both. Using this example, only four variables overlapped between both welding and cutting concrete: (1) number of workers generating contaminant; (2) continuous or intermittent process; (3) degree of enclosure; and (4) posture and distance of worker breathing zone with respect to contaminant. All of the material variables and many of the process variables are specific to the task of interest. Therefore, the task component of this model will have to be expanded and customized to include process, material, and work practice data fields relevant to the specific task of interest.

Conclusions

Occupational hygiene approaches that focus on long-term average exposures without consideration of the task variability associated with construction will fail to yield meaningful information for this industry. Characterization of the contaminant generation rates associated with specific tasks will facilitate effective implementation of controls and work practices aimed at reducing exposures. Such information will also be of use to regulators, such as OSHA or the U.S. Environmental Protection Agency, in standards setting aimed at (1) protecting workers before exposures can be well documented by the employer, (2) requiring the use of specific controls when certain hazardous tasks are performed, and (3) prohibiting unsafe work practices. Finally, the collection of more descriptive detail on the sectors in which construction trades work, the nature of

TABLE 1. Task-Dependent Variables for Cutting Concrete and Welding/Brazing/Burning

	Cutting Concrete	Welding/Brazing/Burning
Process related	1. Cutting equipment 2. Power source (gas versus electric) 3. Blade material 4. Number of workers generating dust 5. Continuous or intermittent cutting	1. Welding process (MIG/TIG/SMA) 2. Number of workers welding 3. Continuous or intermittent welding
Materials	1. Concrete material (% crystalline quartz) 2. Settled dust 3. Particle sizes	1. Consumable 2. Base metal 3. Coatings/residue
Environmental*	1. Degree of enclosure	1. Degree of enclosure
Work practices and worker characteristics	1. Linear cuts/time 2. Wet versus dry methods 3. Posture and distance of worker breathing zone in relation to cut/dust source	1. Electrode use rate 2. Use of welding hood/time 3. Posture and distance of worker breathing zone with respect to fume plume

*Use of mechanical or local exhaust ventilation and personal protective equipment will be collected under controls component for all tasks.

performed tasks, and the frequency and duration with which those tasks are performed will be useful for setting research priorities and designing surveillance strategies that will serve to protect as large a share of the work force as possible.

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Appendix I: Occupational Hygienists' and Construction Safety and Health Specialists' Sample Data Fields

Record Keeping (to be collected by Occupational Hygienists only)

Name________ Social Security No.________

Occupation[a]________ Employer________

Date________ Union Local________

Sector[b]________ Project Name (site)________

Age________ Sex (m/f)________

Name of recorder________ Employer/Affiliation________

Phone number________

(a) Bureau of Census Occupation Code (b) From sector choices (e.g. new construction, industrial renovation etc.)

Task Description

Major Task:________

Major Task No.________ Video/slide no.________

Task Component	TCN	NWT	Tool Type[c]	Tool Name	Materials	Exposure[d]	TCD (mins)

Key: TCN - Task component number; NWT - Number of workers engaged in task; TCD - Tasks component duration
(c) Hand, pneumatic, power, thermal
(d) NOHS hazard code: actual exposure and trade name exposure

Exposure Data

TN	HC	Potential ER[e]	Analyte	SN	C	Units

Key: TN-Task no.; HC-NIOSH hazard code; ER-Exposure route; SN-Sample no.; C-Concentration
(e) 01=inhalation; 02=dermal; 03=ingestion

Appendix I: Continued

Sampling/Analytical Data (to be collected by Occupational Hygienists only)

Personal/Area:

TN	SN	P/A	PI	SL	FR(LPM)	Start T	Stop T	ST (mins)	NIOSH Method
___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___	___	___

Bulk/Wipe:

TN	SN	B/W	Source	Medium	Analyte	Concentration	Units
___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___
___	___	___	___	___	___	___	___

Key: TN-Task no.
SN-Sample no.
PI-Pump/instrument serial no.
P-Personal breathing zone
A-Area
SL-Sampler location
FR-Flow rate
ST-Sample time
T-Time
B-Bulk
W-Wipe

Bystander Data

TN	DS[f]	Bystander Occupation	NW	Sample Taken? (y/n)	SN
___	___	___	___	___	___
___	___	___	___	___	___
___	___	___	___	___	___

Key: TN-Task no.
DS-Distance from source of contaminant
NW-Number of workers in area
ST-Sample time
SN-Sample no.

(f) 0=less than 5'
1=>5' but <20'
2=>10' but <20'
3=>20'

Controls/Environmental Conditions

Ventilation type [g]:_________ Indoors/outdoors (I/O)_______ Degree of enclosure [h]:________

Respirators used? Yes______ No______ What type?______________________

Was worker fit tested? Yes______ No______ How often is cartridge replaced? [i]_________

Gloves used? Yes______ No______ What type?______________________

Protective clothing? Yes______ No______ What type?______________________

Special work practices?______________________
(e.g. standing upright when welding to avoid fumes, keeping kettle lids closed, etc.)

(g) 1=LEV
2=mechanical
3=natural
4=none

(h) 1=1 surface (floor/staging only)
2=2 surfaces
3=3 surfaces
4=4 surfaces
5=5 surfaces
6=6 surfaces

(i) 1=daily
2=weekly
3=monthly
4=less frequently that monthly

Exposure History (to be collected by Occupational Hygienists only)

TN:____________

Duration of task on day of sampling (mins):______________

Percent time engaged in task over years at trade:____________

Number of months per year employed at trade:____________

Number of years at trade:____________

Key: TN-Task no.