A CASE-CONTROL STUDY OF AIRWAYS OBSTRUCTION AMONG CONSTRUCTION WORKERS

SUPPLEMENTAL MATERIALS

EXPOSURE ASSESSMENT DETAILS

Occupational and Exposure History Questionnaire

Based on our experience in the BTMED program telephone interviews have been found to be an effective approach to collecting exposure history data. This is consistent with studies that have found telephone interviews to be superior to postal surveys for respiratory symptoms and risk factors [Brogger et al., 2002]. The telephone questionnaire obtained a lifetime occupational and exposure history through the date of the qualifying BTMED examination. Data domains included:

1. Industry and jobs held for at least six months with start and stop dates (month and year). Jobs within the same industry and occupation were treated as one job. For each job, workers were asked to list the products or services produced, job title/position, and usual work hours per week.

2. For all construction-related jobs, a qualitative assessment of frequency (none to daily) of doing 90 specific construction tasks known to generate VGDF exposures (e.g. cutting concrete, insulation installation, wood sanding, etc.). Open-ended questions were included to allow workers to report other construction-related tasks that created VGDF exposures but were not included in the listed tasks in the questionnaire.

3. For non-construction jobs, workers were asked “Does/did this job expose you to vapors, gases, dusts, and fumes” as this single survey item has been shown to delineate exposures associated with COPD risk [Blanc et al., 2005; Quinlan et al., 2009]. For any job with a positive response concerning VGDF exposure, workers provided a description of tasks resulting in exposures, materials exposed to, and frequency of exposure.

4. A qualitative assessment of exposure frequency (none to daily) for an *a priori* list of other materials associated with respiratory disease in the literature (e.g. coal dust; formaldehyde; beryllium; mercury; polyvinyl chloride fumes (heating or cutting PVC); isocyanates; pesticides, insecticides, or herbicides; diesel or gasoline engine exhaust; grain dusts; and animal feed or fodder). These data were collected for control of potential confounding exposures.

5. Use of respiratory protection (always, sometimes, rarely, or never) and engineering controls such as wet methods or local exhaust ventilation (always, sometimes, rarely, or never) for reported tasks.

6. An assessment of the frequency of bystander exposures to asbestos, man-made fibers, abrasive cutting or grinding of concrete, drywall/plaster dusts, spray painting, sandblasting, welding/cutting, and wood dusts.

7. Service in a branch of the military and if their military jobs resulted in exposures to

VGDF. For any military job with a positive response concerning VGDF exposure, workers provided a description of tasks resulting in exposures, materials exposed to, and frequency of exposure.

8. Exposures to passive tobacco smoke at home and at work, having a blood relative with COPD [Weinmann et al., 2008], and history of pneumonia as a child [Tager et al., 1988]. Respiratory history and smoking history were determined using data from each worker's BTMED exam and any missing data from the BTMED exam was collected during the interviews.

The telephone questionnaire was developed and pilot tested in several ways. First, we assembled two separate focus groups of 10-15 experienced construction workers from DOE's Savannah River and Oak Ridge sites to review the draft questionnaire for ease of understanding (language level), question syntax, and overall questionnaire flow. We also asked focus group participants to identify any common VGDF exposures experienced by construction workers not adequately addressed in the draft questionnaire. Secondly, the draft questionnaire was pilot tested via telephone administration to approximately 25 construction workers identified by BTMED to represent the approximate age and experience range of the COPD cases and controls.

The final telephone questionnaire was administered by four trained interviewers without knowledge of case or control status. Cases and controls were randomly assigned to interviewers. Study subjects were first sent an invitation letter describing the study followed by telephone contact by the assigned interviewer to obtain informed consent and administer the questionnaire.

A minimum of two telephone contact attempts were made before a second reminder letter was sent. Following the second reminder letter at least two additional telephone contact attempts were made. Study subjects were classified as 'failed to contact' due to bad addresses or telephone numbers and 'failed to respond' after no response following two letters and at least four phone calls. Information about the study was also provided on the BTMED web site and included in the BTMED Newsletter.

Cumulative Exposure Indices

Qualitative cumulative exposure indices were assessed for an *a priori* list of 15 common construction-related exposures shown in Table I. The category 'particulates not otherwise regulated' (PNOR) includes all mineral and inorganic 'inert or nuisance dusts' without specific individual U.S. Occupational Safety and Health Administration Permissible Exposure Limits (PEL) [NIOSH, 2015; OSHA, 2015]. A PNOR exposure index was included to allow generation of an overall index for VGDF exposures comparable to those in the published literature. All indices were based on task frequency by job, job duration, and usual work schedule from the interviews in combination with task exposure intensity scoring by industrial hygienists.

The telephone interviews collected information concerning the frequency of performing a specified set of 90 construction-related tasks resulting in exposures to 'vapors, gases, dusts, and fumes' (VGDF). Task frequency from the questionnaire and assigned exposure days per month were as follows:

Worker Reported Task Frequency Description	Assigned Days of Exposure Per Month
None: Did not perform the task	0
Rarely: Performed the task less than once per month	1
Monthly: Performed task 1-2 times per month	2
Weekly: Performed task weekly or most weeks	10
Daily: Performed task daily or almost every day	20

In addition to collecting information about the frequency of performing tasks, exposure intensity for each task reported by workers for jobs held more than six months was scored by three senior American Board of Industrial Hygiene (ABIH) certified industrial hygienists, each with 40 or more years of experience. Hygienists performed intensity scoring for the 15 *a priori* agents and 90 construction tasks in the questionnaire prior to data collection following guidelines proposed by Rice and Heineman [2003]. For each agent, exposure intensities were 'calibrated' relative to NIOSH Recommended Exposure Levels (RELs), ACGIH Threshold Limit Values (TLV), or OSHA Permissible Exposure Levels (PELs) (Table 1). Intensity of exposure for each agent/task combination was recorded on a four-level ordinal scale. These ordinal categories and assigned exposure intensities relative to the reference concentration were as follows:

Exposure Intensity Category and Description	Assigned Exposure Intensity Weight Relative to Reference Concentration
None: Not exposed	0
Low: Less than half the reference concentration	0.5
Moderate: More than half but generally not greater than the reference concentration	1.0
High: Generally higher to much higher than the reference concentration	2.0

Explicit standardization rules on exposure intensity have been shown to improve exposure ratings [McGuire et al., 1998]. In addition to recording exposure intensity, experience and familiarity of the reviewer with the task was ranked on a three-level scale (direct experience, indirect experience, or literature reference only) [Rice and Heineman, 2003].

For derivation of exposure intensity score consensus among the industrial hygienists, three rounds of scoring were used. Any differences among the three hygienists of more than one exposure intensity category were noted and hygienists were asked to further document the rational for their choice of exposure scale based on direct personal experience or published literature. This documentation and rationale was shared among the three hygienists, who were allowed to modify their score if they felt appropriate. For tasks where full consensus was not achieved, the final intensity score used a weighted average of the industrial hygienists' scores, with greater weight being given to raters most knowledgeable concerning the specific exposure and task (i.e. direct experience) [Ramachandran and Vincent, 1999]. Multi-rater kappa statistics were used to assess rater agreement [Chen et al., 2005; Fleiss et al., 2003].

Cases and controls reported a small number of tasks resulting in VGDF exposures in non-construction work and during military service. Many of these tasks were the same or similar to already scored construction tasks and were matched to construction tasks for exposure intensity assignment where appropriate. All remaining unscored tasks were scored for exposure intensity applying the same procedures used for construction tasks by one of the study industrial hygienists (JD). Workers also recorded frequency of exposure to a list of agents associated with bystander exposures in construction and non-construction work. Bystander exposures are typically much less than breathing zone exposures experienced by workers preforming tasks [Donovan et al., 2011]; therefore, bystander intensity was assigned a value of 10% (intensity weight=0.1) of the reference concentration.

Workers also were asked about the normal or usual number of hours worked each week for all jobs held 6 months or more. Cumulative exposure indices were calculated for each exposure scenario (i.e. construction, non-construction, military, and bystander) and these were summed to arrive at an overall cumulative exposure index for each agent. The following relationship was used to generate the cumulative exposure indices by exposure scenario:

$$Agent\ Cumulative\ Exposure\ Index = \sum_{All\ Jobs\ \&\ Tasks}^{N} D * ((H)/40) * ((F) * 12)/240) * (I)$$

Where:

D = Duration of the job in years

H = Average hours of work per week for each job

F = Frequency (days per month) of performing the task or experiencing the exposure (bystander)

I = Assigned exposure intensity relative to the agent reference concentration (0 to 2.0)

N = Number of jobs and tasks contributing to the exposure index for the agent of concern

For presentation of exposure distributions for cases and controls the cumulative exposure indices were categorized using tertile break points for the exposed controls [Hsieh et al., 1991], with unexposed subjects placed in a separate category. For regression modeling cumulative exposure indices were retained as continuous variables and standardized by dividing each worker's cumulative exposure by a value representing an exposure at the upper 95th percentile of the range for all workers. Exposures were thus expressed as a fraction of the upper 95th percentile of the exposure distribution which allowed more directed comparison of exposure-response patterns across the exposures of a priori interest.   Acids and caustics were grouped together as these exposures occurred with low frequency and their mode of action (e.g. respiratory irritation) is likely similar.

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Table I-S: COPD Cases and Controls by DOE Site

DOE Site Description[1]	Cases (n=834)	Controls (n=1243)	Total (n=2077)
Brookhaven National Laboratory	19	29	48
Fernald Feed Materials Production Center (FMPC)	137	183	320
General Electric Company, Cincinnati	23	39	62
Hanford	167	224	391
Idaho National Engineering and Environmental Laboratory	55	66	121
Kansas City Plant	37	53	90
Mallinckrodt Chemical/Weldon Spring	10	14	24
Oak Ridge (All Sites)	114	195	309
Paducah Gaseous Diffusion Plant	44	58	102
Portsmouth Gaseous Diffusion Plant	54	92	146
Rocky Flats Plant	62	101	163
Savannah River Site	112	189	301

[1] Case and control distribution by site not significantly different, Chi-Square=7.47, p=0.76

Table II-S: COPD Cases and Controls by Trade or Job Category

Trade Group or Job[1]	Cases (n=834)	Controls (n=1243)	Total (n=2077)
Asbestos Worker or Insulator	25	37	62
Boilermaker	16	27	43
Carpenter	55	77	132
Cement Mason/Brick Mason/Plasterer	23	12	35
Electrician	128	226	354
Ironworker	50	64	114
Laborer	115	152	267
Mechanical Trades	7	8	15
Millwright	14	19	33
Operating Engineer	53	81	134
Painter	29	30	59
Plumber, Steamfitters, Pipefitter	130	200	330
Roofer	13	9	22
Sheet Metal Worker	45	82	127
Sprinkler Fitter	8	8	16
Teamster	32	34	66
All Other Construction and Non-Construction	91	177	268

[1] Case and control distribution by trade significantly different, Chi-Square= 33.09, p=0.033

Table III-S: Exposure Intensity Scoring Results

Agent or Exposure	Multi-Rater Kappa
Asbestos	0.71
Silica	0.66
Cement Dust	0.82
Man-Made-Mineral-Fibers	0.67
Engine Exhausts (Diesel or Gasoline)	0.71
Acids	0.49
Caustics	0.58
Welding, Thermal Cutting, Soldering, or Brazing	0.80
Metal Cutting, Grinding, and Machining Aerosol	0.80
Paint-Related Aerosol	0.78
Isocyanates	0.66
Organic Solvents	0.69
Wood Dust	0.70
Molds and Spores	0.78
Particulates not otherwise regulated (PNOR)	0.41

Table IV-S: Cumulative Exposure Index Distributions for COPD Cases and Controls

Cumulative Exposure Index	Cases or Controls	Mean (Std Err)	No Reported Exposure[1]	Number (%) of Workers by Tertile[2]		
				Tertile #1 Low	Tertile #2 Medium	Tertile #3 High
Asbestos	Cases	39.3(1.3)	41 (4.9)	240 (28.8)	222 (26.2)	331 (39.7)
	Controls	31.1 (1.0)	81 (6.5)	383 (30.8)	395 (31.8)	384 (30.9)
Silica	Cases	45.7 (1.4)	35 (4.2)	236 (28.3)	240 (28.3)	323 (38.7)
	Controls	38.1 (1.0)	71 (5.7)	388 (31.2)	396 (31.9)	388 (31.2)
Cement Dust	Cases	32.1 (1.1)	48 (5.8)	261 (31.3)	226 (27.1)	299 (35.9)
	Controls	27.9 (0.8)	103 (8.3)	398 (32.0)	365 (29.4)	377 (30.3)
Man-Made-Mineral-Fibers	Cases	17.9 (0.7)	68 (8.2)	233 (27.9)	232 (27.8)	301 (36.1)
	Controls	16.4 (0.6)	115 (9.3)	374 (30.1)	382 (30.7)	372 (29.9)
Engine Exhausts (Diesel or Gasoline)	Cases	10.5 (0.5)	136 (16.3)	171 (20.5)	239 (28.7)	288 (34.5)
	Controls	8.1 (0.4)	236 (19.0)	331 (26.6)	343 (27.6)	333 (26.8)
Acids and Caustics	Cases	0.9 (0.1)	689 (82.6)	46 (5.5)	43 (5.2)	56 (6.7)
	Controls	0.7 (0.1)	1082 (87.1)	53 (4.3)	53 (4.3)	55 (4.4)
Welding, Thermal Cutting, Soldering, or Brazing	Cases	17.3 (0.8)	42 (5.0)	259 (31.1)	247 (29.6)	286 (34.3)
	Controls	15.5 (0.6)	78 (6.3)	384 (30.9)	396 (31.9)	385 (31.0)
Metal Cutting, Grinding, and Machining Aerosol	Cases	39.9 (1.7)	103 (12.4)	227 (27.2)	225 (27.0)	279 (33.5)
	Controls	36.3 (1.4)	165 (13.3)	357 (28.7)	364 (29.3)	357 (28.7)
Paint-Related Aerosols	Cases	6.0 (0.3)	128 (15.4)	229 (27.4)	225 (27.0)	252 (30.2)
	Controls	5.6 (0.2)	209 (16.8)	340 (27.4)	352 (28.3)	342 (27.5)
Isocyanates	Cases	1.3 (0.1)	625 (74.9)	57 (6.8)	64 (7.7)	88 (10.6)
	Controls	1.0 (0.1)	985 (79.2)	85 (6.8)	87 (7.0)	86 (6.9)
Organic Solvents	Cases	28.1 (1.0)	38 (4.6)	249 (29.9)	219 (26.3)	328 (39.3)
	Controls	23.4 (0.8)	84 (6.8)	382 (30.7)	394 (31.7)	383 (30.8)
Wood Dust	Cases	5.0 (0.2)	74 (8.9)	224 (26.9)	240 (28.8)	296 (35.5)
	Controls	4.4 (0.2)	129 (10.4)	363 (29.2)	383 (30.8)	368 (29.6)
Molds and Spores	Cases	14.2 (0.6)	137 (16.4)	193 (23.1)	222 (26.6)	282 (33.8)
	Controls	12.1 (0.4)	237 (19.1)	332 (26.7)	338 (27.2)	336 (27.0)
Particulates not otherwise regulated (PNOR)	Cases	89.4 (2.7)	28 (3.4)	232 (27.8)	237 (28.4)	337 (40.4)
	Controls	74.2 (2.0)	67 (5.4)	389 (31.3)	398 (32.0)	389 (31.3)
ALL VGDF	Cases	367.0 (11.2)	12 (1.4)	237 (28.4)	249 (29.9)	336 (40.3)
	Controls	310.4 (8.3)	31 (2.5)	398 (32.0)	410 (33.0)	404 (32.5)

[1] Number and percent of workers not reporting exposures included in the cumulative index.
[2] Tertile cut points were based on the distribution of exposures for exposed controls. The percent ( ) represents the percent of the total distribution of exposures, including workers with no reported exposure.

Table V-S: Assessment of Cigarette Smoking and Exposure Interactions

Cumulative Exposure Index	RERI[1] (95% CI)
Asbestos	1.03 (0.95-1.11)
Silica	1.03 (0.95-1.12)
Cement Dust	1.01 (0.95-1.09)
Man-Made-Mineral-Fibers	1.00 (0.94-1.08)
Engine Exhausts	1.01 (0.92-1.10)
Acids and Caustics	1.06 (0.99-1.16)
Welding, Thermal Cutting, Soldering, Brazing	1.01 (0.95-1.09)
Metal Cutting, Grinding, and Machining Aerosol	0.99 (0.93-1.06)
Paint-Related Aerosols	1.02 (0.96-1.09)
Isocyanates	1.01 (0.95-1.10)
Organic Solvents	1.02 (0.95-1.10)
Wood Dust	1.05 (0.98-1.13)
Molds and Spores	1.07 (1.00-1.16)
Particulates not otherwise regulated (PNOR)	1.03 (0.96-1.12)
All VGDF	1.03 (0.95-1.12)

[1] Relative excess risk due to interaction (RERI) based on a linear odds-ratio model. RERI represents the increased risk for a 10% increase in cumulative VGDF exposure and 10 pack-years of smoking compared to the sum of risks for smoking and VGDF exposure. Likelihood-based 95% confidence estimates for each RERI are shown.