COPD Risks in Carpenters

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Abstract:

COPD is the 4th leading cause of death with 12.1 million prevalent cases and there are indications that morbidity and mortality from COPD will be more prevalent in the coming years. Preliminary evidence suggests that carpenters experience excess risk of work-related COPD. Tobacco smoking is a known causal factor but there is growing evidence that occupational exposures to vapor, gas, dust and fumes increases COPD risk with occupational attributable risks of 15-20%. Very few studies have data to investigate quantitative exposure-COPD relations or modification by smoking and little is known about risk from more moderate exposures to particulate mixtures. Studying effects of mixed exposures is important since mixtures are typical of many work environments especially for carpenters.

Evidence of a relationship between occupational dust exposures and chronic airway disease, including chronic obstructive pulmonary disease (COPD), has been demonstrated in a number of studies in occupational and community settings. Apart from studies focused on the classical dusty trades, however, very little is known about the possibility of risk from more moderate exposures to a diverse mixture of different types of particulates. Evidence is mounting for mechanisms that might underlie a relatively nonspecific toxic effect from particulate exposures. In addition to respiratory tract irritation, high particulate exposures can overload the clearance mechanisms of the lung, producing a cascade of responses that may culminate in chronic lung injury. To contribute to the study of risk associated with exposure to a mixture of particulates, the investigators propose to target a working population of union carpenters. Carpenters have a diversity of aerosol (wood dust being only one) and chemical exposures and excess risk for pulmonary disease. Apart from studies of occupational asthma, there have been few investigations of respiratory disease associated with this trade, despite the fact that carpentry is one of the largest specialty trades among construction workers. This is a pilot investigation of the risk among carpenters of chronic airway obstruction other than asthma. We have been able to develop methods to (1) identify incident cases of COPD in the Carpenters Combined Benefits Fund of Massachusetts medical insurance records database and (2) develop a job-specific matrix that characterizes a diverse range of aerosol and gas exposures associated with carpenter jobs and job task. In addition we have determined the feasibility of carrying out a case-control study by matching COPD incident cases to members of the fund who were eligible for insurance coverage at the time of diagnosis of the case. This has permitted us to submit a grant proposal for undertaking this case control investigation to provide quantitative data on the associations between COPD and different aerosol exposures experienced by carpenters while adjusting appropriately for cigarette smoking history.

Highlights/Significant Findings

The Fund membership is 10,500 active and 500 retired. Average age of active members is 42 and average duration of membership is 9 years. Between 1991 and 2004, 825 carpenters received medical care for chronic bronchitis, emphysema, asthma or chronic airways obstruction, n.e.c. (ICD diagnoses 491, 492, 493.2 and 496), half had a chest radiographic test and 25% some pulmonary function tests. Fund records contain work/employment histories back until 1980 and the organization of the records permits the selection of age and gender matched controls. A series of key informant interviews were conducted at Carpenter locals to develop a taxonomy of carpentry work including construction stage, specialty, operations, tasks, tools and materials used. The taxonomy formed the basis of a semi-quantitative exposure assessment that found that both the agents and the levels of exposure provide an adequate range for future exposure-response analyses and that work histories can be collected with sufficient detail to allow historical exposure estimates to be developed for the study population.

This study determined that it is feasible to undertake a case-control study of COPD among union carpenters. The Fund was able to provide access to their medical insurance database for this pilot study using electronic records dating from the early 1990s. The results of the pilot study found that 1) the database proposed for the study has enough cases to provide adequate power for such a study 2) electronic records include ICD codes for all and CPT codes for many, 3) the database organization will permit matching to identify eligible controls. In addition, we determined that carpenters 1) have a range of exposure levels to a mixture of particulate and chemical agents, 2) engage in a range of tasks and operations with different types and levels of exposure and .3) that it is feasible to collect task or operation-specific work history data on active and retired carpenters.

Translation of Findings

The study established a methodology for conducting exposure assessment research in the construction industry. Specifically, the identification of specialty and major operation/tasks and the collection of work histories based on these factors will significantly improve the reconstruction of historical exposures. The study describes the method for developing the taxonomy framework for characterizing work in one construction trade (carpenters), but can be applied to other construction trades.

Outcomes/Relevance/Impact

The carpenters' taxonomy is a systematic subdivision of carpentry work and its associated chemical and particulate exposures which organizes what appears to be chaotic and haphazard construction site activities. It has a hierarchical framework of stages and operations with detailed information on specialty, tasks, tools and materials used, direct exposures, enclosure, activities of other trades, and indirect exposures obtained through interviews. The taxonomy can be used to identify the direct and indirect exposures associated with the different aspects of carpentry work, the sources of the exposures, and the factors affecting exposures, thereby providing and opportunity to work safely through controlling or preventing the exposures.

Many studies have struggled with the definition of task resulting in multiple task definitions and great difficulty in comparing study results. In the taxonomy, the identification of tasks within operations, specialty and stages provides common terminology to facilitate the compilation of data from multiple studies in the future, and permits more efficient exposure data collection and the generalization of task information to other construction settings. It also permits the identification of when and how often a task is performed by carpenters during any stage of construction activities.

Such detailed and systematic classification of carpentry work has previously not been reported and can find a variety of usage in: planning and scheduling work; identifying appropriate personal protective equipment, administrative or engineering controls; selecting particulate and chemical substances to monitor; or assigning exposures for epidemiologic studies. This taxonomy formed the basis for further exposure assessment and the creation of a surrogate of exposure intensity for particulate and chemical exposures associated with each operation/task combination. The exposure intensity scores can be used in epidemiologic studies to assign exposures to individuals, or in risk assessment to prioritize operation/tasks and exposures for control measures.

Scientific Report

Background

Carpenters may be involved in all phases and types of construction activities ranging from residential and commercial construction to the construction and maintenance of steel structures, bridges, highways and tunnels. On these projects, carpenters may be exposed to a wide range of substances directly as a result of their activities or indirectly through the activities of others surrounding them. Some of these trades that work in close proximity to the carpenters include painters, welders, sheet metal workers, insulators etc. Due to the nature of their work, carpenters work in a variety of industries and work setting, potentially exposing them to substances not typical of the carpenters work. These exposures may be responsible for the range of adverse health effects observed/reported among union carpenters such as asthma, COPD, bronchitis, dermatitis.

Chronic Obstructive Pulmonary Disease (COPD) is defined as a disease state characterized by airflow limitation that is not fully reversible [1]. The airflow limitation is usually progressive and associated with an abnormal inflammatory response of the lungs to noxious particles or gases. Persons with COPD include those with chronic bronchitis and/or emphysema with accompanying obstructive disease [2]. Those with either of these two conditions but without obstruction are generally not considered to have COPD [3,4]. While using the term in this manner largely excludes asthma [5], chronic asthma is difficult to distinguish and a person with COPD may present with evidence of some irreversible airway hyperreactivity [6].

In the US, COPD morbidity and mortality has been steadily increasing with higher rates among men than women. In 2003 there were an estimated 12.1 million people in the US suffering from COPD. It is the 4th leading cause of death in the US [7], and there are indications that it will become the 3rd by the year 2020, as well as the 5th leading cause of disability, worldwide [8,9]. COPD begins to be a significant cause of death in the fifth decade [10] and hospitalizations for exacerbations greatly exceed those for asthma [11,12].

While tobacco smoking is the most important causal factor for COPD, there is growing evidence that occupational exposures to vapor, gas, dust and fumes increases COPD risk, both independently as well as through interaction with smoking [13-19]. The interaction between smoking and occupational exposures is complex, and is reported to be additive in some studies and multiplicative in others depending on the exposure circumstances [19,20]. The fraction of COPD attributable to occupations (population attributable risk-PAR) is variable, however, several recent studies have reported average or median PAR in the range of 15-20% *after* accounting for cigarette smoking [7,13,19].

The best studies of occupation and COPD have examined the association of long-term exposure to dusts which are also fibrogenic. These studies suggest that airflow

limitation is present among both smokers and non-smokers with at least some kinds of prolonged particulate exposures [13,21,22]. Very few of these studies, however, have adequate data to investigate quantitative exposure-COPD relations or modification by smoking and they are mostly focused on the classic "dusty trades" of mining, quarrying, etc. Very little is known about potential risk from more moderate exposures to a diverse mixture of different types of particulates. Epidemiological and experimental evidence has linked COPD to exposure to isocyanates [23], grain, cotton and wood dust, solvents, cadmium, mineral dusts [13,24], metals [25,26] sulfur dioxide, oxides of nitrogen, vanadium and endotoxin [27] and, more recently among welders [28-30]. The effects of mixed exposures, however, are important to understand since mixtures are a typical feature of the work environment for many carpenters as well as other occupational groups.

Becklake has shed some light on the likelihood that mixed exposures at work are associated with COPD risk [31]. She reviewed the evidence available in community based epidemiologic studies of respiratory disease. Studies in the review included both cohort and cross-sectional designs to study communities in six countries including the U.S. [32-40]. All reported increased airflow limitation associated with work exposures to varying combinations of dusts, fumes and gases. Smoking was considered and adjusted for in all of these studies. Despite the crude categorization of exposure as "exposure to vapors, gases, dusts or fumes (VGTF)" the strong association of VGTF exposure with COPD suggests that there may be an underlying mechanism involving a non-specific particulate response by the lungs and that cumulative particulate burden in the lungs may be a useful exposure index. Becklake has called for "...better modeling on the exposure side to accommodate the complexity of workplace exposures [31, p2]."

There is limited evidence from occupational mortality surveillance data that carpenters experience excessive respiratory mortality. Using mortality statistics from 26 states for the years 1987-1996 NIOSH reports that carpenters have an excess PMR for COPD (1.49 - 95% CI 1.46-1.52) [41] - among the top 15% of all occupations with significantly elevated mortality for COPD. In its 2003 report NIOSH noted significantly increased PMRs for the construction industry (1.19); construction trades n.e.c. (1.81); drywall installers (1.48); and carpenters (1.30) [42]. In a study of German construction workers that included a large number of carpenters, an elevated prevalence of obstructive lung disease was identified when compared to white-collar workers [43]. And in a Swedish cohort mortality study of construction workers, risk of COPD was evaluated for exposure to inorganic dust (asbestos, MMMF, cement, concrete and quartz), gases and irritants (epoxy resins, isocyanates, organic solvents), fumes (diesel exhaust, metal fume and asphalt) and wood dust [20]. The study reported significant elevated risks for any airborne exposure (RR: 1.12), inorganic dusts (RR: 1.16) and fumes (RR: 1.22). There was considerable overlap between the four exposure groups, and in a Poisson regression model, only inorganic dust remained significant after the introduction of the other exposure variables in the model.

One cohort study of over 10,000 carpenters utilized medical insurance records to examine risk of several different respiratory disease diagnoses [44]. This study, of union

carpenters in the state of Washington, used a database similar to the one that we propose, and its findings are useful for evaluating the feasibility of our approach. Bronchitis was identified in over 50% of the cases with lung disease while asthma, chronic obstructive airways disease (NEC), chronic bronchitis, and emphysema accounted for 23%, 10%, 5%, and 2.4% of lung disease reports, respectively. The incidence of various types of lung disease was evaluated by length of time in the union. For COPD not otherwise classified (ICD-9 496), there was a fairly strong positive trend suggesting increasing risk with increasing duration of employment in the trade.

Most epidemiologic studies that have investigated morbidity and mortality among construction workers including carpenters have suffered from poor characterization of exposures. These studies have used workers' trades or specialties as proxies for exposure [42,44,45] or have used an ever/never format of self-reported exposures to various construction materials [46,47]. Few of these studies attempted to obtain information on duration or intensity of exposure [48] or frequency and duration of materials used, primarily due to the dynamic nature of construction work and the absence of documented work histories. The review by Becklake [31] suggested that the lack of quantitative exposure assessment was one of the persistent problems of the studies of COPD, and called for improved exposure assessment.

To date, there are few exposure surveillance studies that have investigated exposures in the construction industry [49-53]. Even fewer studies have focused on construction carpenters' exposures [54]. Due to the variable nature of construction work, the need to use operation/task as the focus of exposure assessment has been demonstrated in previous studies [55,56]. However, task/operation based exposure data for the construction industry are minimal [50,51,56-58] and practically negligible for the carpenters' trade [54].

Often times, exposure measurements are not available for all jobs or tasks done by workers or in all time periods. When exposure measurements are unavailable, various methods have been used to obtain quantitative or semi-quantitative estimates of exposure. In the occupational setting, these methods include self reported exposures, employment in industry of job classification, use of generic or industry specific job exposure matrix, or expert judgment to infer exposures from jobs or task [59].

Study Objectives

The specific objectives of this pilot study were to develop and evaluate methods to: 1) identify incident cases of COPD in the Carpenters Combined Benefits Fund of Massachusetts medical insurance records data base; and 2) assess a diverse range of different aerosol and gas exposures occurring in carpenters' jobs. The outcome of the pilot study were intended to be methods that can be applied in a subsequent case control investigation designed to provide quantitative data on the associations between COPD and different aerosol exposures experienced by carpenters.

Specific Aims

1. Construct a cohort of carpenters eligible for medical insurance benefits from the Carpenters Combined Benefits Fund of Massachusetts and evaluate the quality of the data.

   A. Develop a file of eligible members and the months of eligibility by year during the study interval.

   B. Develop the capacity to link individual eligible members to their employment histories.

2. Identify both incident and prevalent cases of COPD in the Combined Benefits Fund database over a ten year study period (1991 - 2001).

   A. Identify reports of COPD and related conditions using ICD-9 diagnoses provided in medical visit records for the past ten years and develop an algorithm to define incidence for each case within the study period and estimate of date of onset.

   B. Evaluate validity of the data over time by examining consistency in repeated events by standard demographic and membership variables including: age, gender, ethnicity, membership and subtrade.

   C. Estimate incidence and prevalence rates of COPD and related conditions by demographic and subtrade variables and calculate statistical power for the case-control study.

3. Develop a survey instrument to determine historical exposures to unregulated particulates as well as specific toxic chemicals

   A. Develop a taxonomy of carpentry jobs and tasks crosstabulated with types of exposures through use of key informant interviews and focus groups with master carpenters.

   B. Develop capacity to link individual members to work history.

   C. Explore several methods for eliciting information on the types of jobs and tasks done by a worker during the time covered by each work history entry.

   D. Develop survey questions that seek information needed to develop semiquantitative estimates of cumulative exposure to specific agents using information on frequency/duration and exposure modifiers.

Aim 1. Construct a cohort of carpenters eligible for medical insurance benefits from the Carpenters Combined Benefits Fund of Massachusetts and evaluate the quality of the data.

Aim 1A. Develop a file of eligible members and the months of eligibility by year during the study interval.

An effort was made to reconstruct a file of eligible members with adequate demographic information to provide a proper denominator for the study and to determine feasibility of identifying members eligible to serve as controls in any case-control study proposed for future funding.

In the end, the legal staff of the Fund interpreted the privacy requirements of the Health Insurance Portability and Accountability Act to constrain the Fund from releasing information about its eligible members without a signed medical release form or a convenient mechanism to eliminate personal identifiers. The Fund was prepared to provide masked information about individuals with medical visits with the ICD-9 codes for COPD because the number was small enough to permit blackening the personal identifiers for each individual on the paper report provided. Such an approach was not considered possible for the entire list of eligible members for the time period 1991-2005 as the current eligible membership is estimated to be approximately 10,000.

The interest in a list of eligible members was to a) define a denominator for the COPD cases that would allow estimating rates of COPD among the Carpenters membership and b) confirm that proper controls could be selected for each of the COPD cases in the future plan for a case-control study. The information technology department at the Fund determined that the records on membership eligibility are organized electronically in a manner that will permit the selection of age and gender matched controls for each case from those eligible for medical insurance at the date of first visit for a COPD diagnosis among those designated as cases. They will be prepared to supply names, current addresses and telephone contact information on these members and are prepared to identify which are "cases" once informed consent for participation in the study is obtained.

Aim 1B. Develop the capacity to link individual eligible members to their employment histories.

A member's eligibility for medical insurance benefits is determined by number of hours worked in each six months for participating contractors. To confirm eligibility each contractor regularly submits lists of hours worked by members. This record is maintained by the fund and can be linked to each member as long as the work performed was for one of our contractors. This information was not provided during the grant period due to the understanding that HIPPA constrained the Fund from sharing this information. However, the Fund did determine that the information would be available with signed releases from members. Therefore, it is understood that the

capacity exists to link individuals to employment histories is available once a study subject provides written permission

Aim 2. Identify both incident and prevalent cases of COPD in the Combined Benefits Fund database over a ten year study period (1991 - 2001).

Aim 2A. Identify reports of COPD and related conditions using ICD-9 diagnoses provided in medical visit records for the past ten years and develop an algorithm to define incidence for each case within the study period and estimate of date of onset.

We were able to determine that, for the period 1991 through 2004, that there were 825 carpenters who received medical care for chronic bronchitis, emphysema, asthma or chronic airways obstruction, n.e.c. (ICD diagnoses 491, 492, 493.2 and 496). Over half of the cases were associated with ICD-9 496 (Table 1).

TABLE 1: ALL COPD CASES IN THE FUND 1991-2004

ICD9	Frequency	Percent
491	250	30%
492	42	5%
493.2	33	4%
496	493	60%
Other*	7	1%
Total	825	100%

*Different combinations of 491, 492 and 493.2

Only a portion of records included CPT codes in the electronic file. Of those half reported some chest radiographic test and an additional 25% some form of pulmonary function tests. Only 5% of those with a COPD diagnosis were recorded as having an "initial evaluation".

Initial and follow-up visits for COPD did not follow any discrete patterned. Instead, we determined that it will be possible to identify incident cases according to the following rules: Initially an incident case can be defined as those with a first doctor visit for ICD9 codes 491 (Chronic Bronchitis), 492 (Emphysema), 493.2 (Chronic Obstructive Asthma) and 496 (Chronic airway obstruction, not elsewhere classified), preceded by at least 1 year without this diagnosis (working and eligible for health benefits from The Fund). The Fund database can be queried to identify potential cases of newly diagnosed COPD based on the diagnosis codes and the inclusion and exclusion time windows described above.

An algorithm was developed to match all records for the same individual in order to eliminate duplicate records and identify unique individuals. A probability-based matching algorithm will permit us to identify and evaluate individually, records of close,

but not perfect matches which are possibly true matches corrupted by data entry errors.

Aim 2B. Evaluate validity of the data over time by examining consistency in repeated events by standard demographic and membership variables including: age, gender, ethnicity, membership and subtrade.

When data were examined by first visit for any one of the four diagnostic categories, over 75% were first seen after age 45 (Table 2). Less than 1% of the cases occurred among females (Table 3). Ethnicity of the study population was not available from electronic records in The Fund database and

TABLE 2: AGE DISTRIBUTION: 1991-2004

	ICD 9 CODES					
Age group	491	492	493.2	496	Other	Total (%)
< 25	1 (0.4)	2 (4.8)	1 (3.0)	0	0	4 (0.5)
25-34	20 (8.0)	2 (4.8)	2 (6.1)	14 (2.8)	0	38 (4.6)
35-44	79 (31.6)	6 (14.3)	10 (30.3)	58 (11.8)	2 (28.6)	155 (18.8)
45-54	69 (27.6)	9 (21.4)	13 (39.4)	111 (22.5)	3 (42.9)	205 (24.8)
55-64	55 (22.0)	13 (30.9)	4 (12.1)	163 (33.1)	2 (28.6)	237 (28.7)
65-74	21 (8.4)	8 (19.0)	3 (9.1)	124 (25.1)	0	156 (19.0)
≥ 75	5 (2.0)	2 (4.8)	0	23 (4.7)	0	30 (3.6)
Total	250 (30.3)	42 (5.1)	33 (4.0)	493 (59.8)	7 (0.8)	825 (100)

Table 3: COPD by gender 1991-2004

Gender	Frequency*	Percent
Male	816	99.15
Female	7	0.85

* missing=2

Current claims for the time period 1991-2004 provided information linking the member making the claim to the local with which the member was affiliated. This information on local affiliation was aggregated by ICD9 code and then further grouped according to primary specialty for those locals that were known to primarily involve one subtrade (Table 4).

The survey showed there are 19 carpenters' locals in Massachusetts, 5 of which are specialized locals including: Millmen and Shop carpenters, Pile drivers, Wood framers, Millwrights and Floor coverers. The remainder 14 locals conduct the full range of carpentry work. The specialties practiced by union carpenters include: drywall installation, ceiling installation, concrete formwork, frame work, finishing work, pile driving, scaffolding, millwrights, floor laying/covering, maintenance carpentry, millwork and shop carpentry. Generally, union carpenters practice their trade in a wide range of worksites including residential and commercial building construction, construction of bridges, tunnels, roadways, elevated highways and other industrial structures. Some

specialties such as millwrights and maintenance carpenters may work in any industry while the millmen and shop carpenters work in wood working industries. Given the diversity of worksites in which carpenters practice their trades, they are potentially exposed to a wide range of particulate and chemical exposures, many of which are not considered typical of carpenter's exposures.

The carpenters of Massachusetts were determined to include the following specialty locals:

Millmen, shop carpenters and door, hardware and finish workers: Cabinet makers and mill workers cut, shape and assemble wood products including moldings and furniture. They also fabricate fixtures, which require the use of metal, plastics and glass. These workers operate a number of machineries such as saws, planers, joiners and shapers. The door, hardware and finish workers put finishing touches on a project such as installation of locking systems.

Pile drivers: Work with pile driving rigs where they drive different types of piles into the earth such as metal sheet plies to hold back dirt during excavations or metal and concrete piling as part of building foundations. They also drive wood and concrete piling to hold up docks, wharves and bridges, and also work as commercial divers in underwater construction. Pile drivers often work with a variety of hand and power tools including: including welding and torch cutting equipment.

Wood framers: Generally work in residential construction of single and multiple family homes, apartments, condominiums and other low raised commercial buildings. They assemble and erect framework out of different materials (wood or metal), build partitions and even do finish work in smaller residential construction projects.

Millwrights: Primarily work with metals, machinery and equipment. They install, fit, perform maintenance, conduct precision work and repair these machineries and equipment in all industries from construction to power plants.

Floor coverers: Floorlayers install carpeting, hardwood flooring, soft tiles, linoleum products, and vinyl or rubber products. They cut, fit and install various types of floors as well as underlayment to ensure smooth surfaces for the finished floor.

General Carpenters Locals: Workers in these local are involved in almost all aspects of carpentry work. The include carpenters who work as form workers (constructing and taking apart forms for pouring concrete), interior systems carpenters (installation of cabinets, shelves, molding), exterior work carpenters, lathers (framework for plasterers) and drywallers (ceiling and wall paneling).

TABLE 4: CARPENTRY SPECIALTIES BY ICD9 CODES					
	ICD9 Codes				
Specialty	**491**	**492**	**493.2**	**496**	**Other**
Floorcoverers	7	4	0	20	0
General Carpentry	191	27	29	382	5
Millmen and Shop Carpenters	7	2	1	12	0
Millwrights	11	0	1	29	0
Piledrivers	16	3	2	23	1
Wood Frame Carpenters	6	0	0	3	1
Others (Unspecified locals)	12	6	0	24	0
TOTAL	250	42	33	493	7

Aim 2C. Estimate incidence and prevalence rates of COPD and related conditions by demographic and subtrade variables and calculate statistical power for the case-control study.

Denominator data were not provided by The Fund (see explanation earlier). Therefore, estimation of incidence and prevalence rates of COPD could not be made.

Aim 3. Develop a survey instrument to determine historical exposures to unregulated particulates as well as specific toxic chemicals

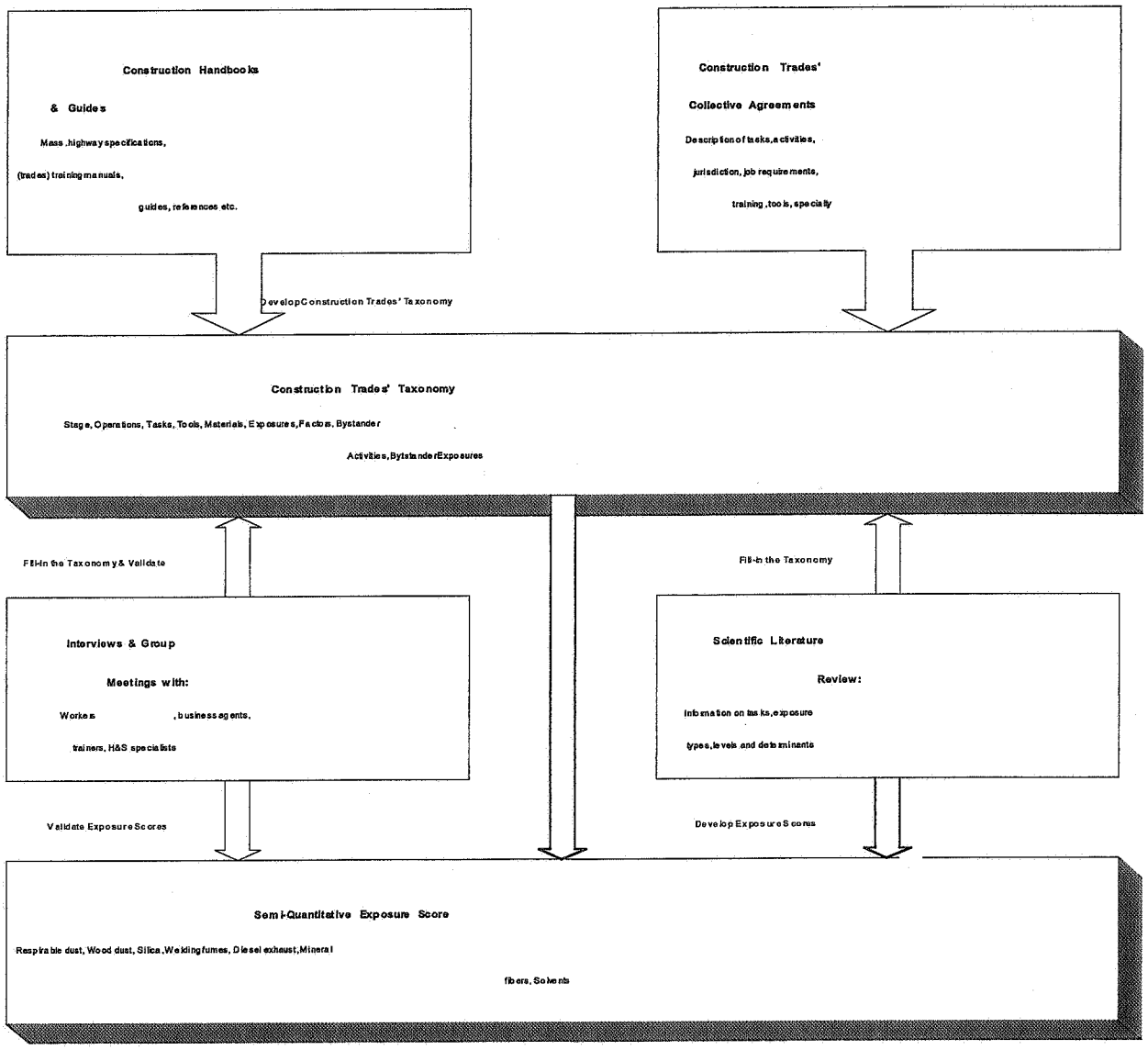
Aim 3A. Develop a taxonomy of carpentry jobs and tasks crosstabulated with types of exposures through use of key informant interviews and focus groups with master carpenters

Due to the nature of the construction industry, very few exposure surveillance studies have been conducted, and few exposure data are available. In manufacturing environment where the processes, plant characteristics and job tasks remain fairly constant, exposure assessment is accomplished fairly easily through random sampling methods. However, because of the dynamic nature of the construction environment and the multiple direct and indirect sources of exposures, significant tasks and exposures can be missed if the total scope of work is not taken into consideration. This makes exposure assessment in the construction industry challenging, and historical exposure reconstruction a daunting endeavor. Given the vastness of the construction industry and the diversity of tasks, exposures and work setting, the conventional exposure assessment strategies will not provide representative exposure estimates. A new framework is required to perform a complete characterization of the construction work as it progresses through the various stages of construction accompanied by changing worksite, technology used, tasks and tools used, determinants of exposure and exposure hazards. A broad framework (taxonomy) for classifying construction work into stages of construction, operations, tasks and activity has been developed by the COHP to assess ergonomic

exposures in highway and heavy construction [60]. This model was modified and applied to assess particulate and chemical exposures in heavy and highway construction projects [49]. The construction taxonomy was further developed to classify carpenters' work into construction types, stages, specialty, tasks, tools and materials used, direct and indirect exposures through a series of interviews with master carpenters and union representatives.

The carpenters' taxonomy and the table of tasks and exposure intensity were developed in several steps using a variety of information sources as summarized in Figure 1 below. The information sources were either general to the construction industry or specific to the carpenters' trade.

Figure 1. Information Sources for Developing the Carpenters' Taxonomy



The Massachusetts Standard Specifications for Highways and Bridges formed the basis for classifying carpentry work within construction stages as described by Moir et al., 2003. Other carpentry specific handbooks, manuals, collective agreements, apprenticeship training materials and texts were used to fill in information on stages, operations, tasks, materials and tools used [44, 45, 51, 54, 60-67]. Open-ended interviews were then conducted with master carpenters, carpenter trainers and business agents for the locals, and health and safety personnel to validate the taxonomy and fill in additional information on the elements of the taxonomy. Published literature was also searched and reviewed for on task based exposure information. The final taxonomy was

used to develop a table of operation/task based exposure scores, which was also reviewed by carpenters, their business agents and health and safety professional.

+A series of key informant interviews were conducted with master carpenters, carpenter trainers and business agents for the locals to characterize carpenters' work. The interviews were open-ended and aimed to classify carpentry work into construction types, stages, specialty, operation/ tasks, tools and materials used. Initially, several meetings were held with 2 carpenters' trainers at the Boston Carpenters Apprenticeship & Training Center in Brighton to develop draft taxonomy of carpenters' work. Interviews were then conducted with the representatives from 9 carpenters' locals in the greater Boston area to modify and validate the draft taxonomy. These locals included all the specialty locals (5) and 4 general carpentry locals. Table 5 displays the various personnel interviewed and the number of interviews conducted at the different carpenters' locals.

TABLE 5: List of Carpenters' Locals and Personnel Interviewed

Local	specialty	Personnel Interviewed	Frequency	
			Interviewed	Visits/Calls
Carpenters Training Center-Brighton	Training	Carpenters' Trainers	2	4
Local 51 Dorchester	Millmen & Shop Carpenters	Business Agent	1	1
Local 56 Boston	Piledrivers	Business Agent H & S Rep.	1 1	2
Local 723 South Boston	Wood Frame	Business Agent	1	1
Local 1121 Allston	Millwrights	Business Agent	1	2
Local 2168 Dorchester	Floor coverers	Business Agent	1	2
Local 40 Cambridge	General Carpentry	Carpenter	2	1
Local 67 Dorchester	General Carpentry	Business Agent	1	1
Local 111 Methuen	General Carpentry	Business Agent Carpenter	2 2	2
Local 275 Newton	General Carpentry	Business Agent Carpenter	1 2	1
OSHA Office Methuen	Construction Industry	OSHA Inspector	1	2

The Business Agents were informed of the project in the initial telephone contact and face-to-face interview times were setup. Business Agents were also requested to provide the names and contact information of carpenters who had log-term experience in the trade and were knowledgeable about exposures associated with the different aspects of carpentry work. Interviews with these carpenters were arranged by the Business Agents and were held at the local offices. In these individual or group interviews, subjects were asked to review and modify the taxonomy, add tasks, tools and materials used for tasks, and identify the direct and indirect exposures associated with each operation/task as well as other specialties working nearby. Additional information on tasks and exposures was obtained from a review of the literature on

carpenters or construction work. The final table of carpenters' taxonomy is presented in Table 6 (at the end of the report).

The basic components of the taxonomy, which classifies construction carpenters work into three levels, are: construction stages, operations and tasks for the different types of construction activities. The construction activities include: residential construction (SIC: 1521-single family houses, 1522-residential buildings, hotels, motels, dormitories, 1531-operative builders, apartments, condominiums); commercial construction (SIC: 1541-industrial buildings and warehouses, 1542-commercial, institutional, recreational and religious buildings); highways and street construction (SIC: 1611-roads, streets, alleyways, airports, side walks, parkways); elevated highway and bridges construction (SIC: 1622-bridges, viaducts, elevated highways, all tunnels); and other heavy construction (SIC: 1623-water, sewer pipelines, communication and power lines, 1629-other heavy construction, athletic fields, canals, dams, hydroelectric plants, nuclear reactors, petroleum refineries, piers). The stages, operations and tasks are defined as:

Stages: Construction stages are the highest level of construction work organization, which consist of large engineering processes. Stages generally occur sequentially as ordered in Table 6, but multiple stages can occur simultaneously in large construction projects. The sequence of stages and their associated operation and tasks can have significant impact on the types and levels of indirect (bystander) exposures generated.

Operations: Operations consist of steps required to complete a stage [60]. Not all operations are performed to complete a stage in different construction projects.

Tasks: Tasks are defined as a sequence of steps taken by a worker to complete an operation [60]. While the concept of task is central to exposure assessment in the construction industry, there is no agreed-upon definition of tasks. The definitions of tasks tend to vary depending on the project. For practical sampling purposes, a combination of operation and task is taken to represent task to allow sampling of full-shift. Unless direct reading instruments with data logging capability is used in conjunction with observation of work or video monitoring, task based sampling as defined in this taxonomy is not practical. As described in Specific Aim 3D, a combination of operation and task was used to define operation/task and conduct semi-quantitative exposure assessment.

Each task is associated with tools used to complete the task, a range of materials used and exposures, indirect exposures resulting from activities of other specialties or trades occurring simultaneously, and factors affecting task exposures. The factors affecting task exposures determine the exposure intensity and are described in Specific Aim 3D.

Within the locals union carpenters tend to work in one or more specialties and sub-specialties. Various carpenters specialties function within different stages of the construction. These specialties include:

1. Ceiling installation
2. Concrete formwork
3. Drywall and plasterers
4. Finishing (interior systems and exterior)
5. Floor layers/coverers
6. Framing
7. Insulators
8. Pile driving
9. Scaffolding

Table 6 represents the most complete information available on carpenters taxonomy and direct and indirect exposures. The taxonomy facilitates a comprehensive evaluation of direct and indirect exposures associated with tasks or operations. This taxonomy will for the basis for conducting the semi-quantitative exposure assessment as well as the quantitative exposure assessment proposed in a future study of carpenters.

Aim 3B. Develop capacity to link individual members to work history.

During the interviews with union representatives, work/employment histories were sought from the local unions through their own records or from the Combined Carpenters Benefits Fund of Massachusetts (CCBFM). Records of work/employment history at the local unions were available from only a few local and were mostly incomplete. However, work/employment histories from the CCBFM go back to the 1980's and contain information on the dates and contractors that the members worked for.

The utility of the employment histories and the ability to translate the information contained in them into work/exposure history is crucial for the proposed case control study. This employment history does not provide information of job functions or work/exposure history, but can be used as a means to assist workers in remembering their work history. Therefore the employment history from the Carpenters Fund (CCBFM) will be summarized for each year of employment to identify contractors for whom the carpenter worked in each calendar year. The contractor employment history will be used to assist workers in their recollections of their work history during interviews with workers.

Aim 3C. Explore several methods for eliciting information on the types of jobs and tasks done by a worker during the time covered by each work history entry.

A work history questionnaire was developed during interviews with the carpenters. Initially a detailed survey questionnaire was developed which collected information on projects worked on, the contractors, the stage of construction, operations, tasks, tool and materials used, and fraction of time spent on tasks. This was simplified after interviewing the carpenters on the questionnaire's clarity and whether the level of detail on exposures, work history and operation/tasks were reasonable to acquire through an interview. The final version of the work history questionnaire was developed through interviews with carpenters at 5 carpenters locals, and gathers information on the time spent on the different operation/tasks exposed to various

exposure agents or materials used by the carpenters. This information will be used to obtain estimates of past exposures.

Aim 3D. Begin development of survey questions that seek information needed to develop semiquantitative estimates of cumulative exposure to specific agents using information on frequency/duration and exposure modifiers.

The taxonomy serves as a task-exposure matrix, which takes into consideration the dynamic nature of the construction environment as well as the multiple direct and indirect sources of exposure. This classification was simplified by combining the operation and tasks into one variable, and formed the basis for conducting the semi-quantitative exposure assessment for each operation/task using factors reported in Table 7.

TABLE 7. Components of the Semi-Quantitative Exposure Assessment Model

Factors	Values	Scores
Source	None; Indirect; Direct	0 - 2
Manner of Handling	Move/handle solids or non volatile material; Move/handle particulate or volatile material; Low speed cut, drill etc. or low temperature/energy; High speed cut, drill etc. or high temperature/energy	1 – 4
Degree of Work Enclosure	Open; Partial; Enclosed	1 – 3
Controls	Present; Absent	1 – 2
Fraction of Component	<25%; 25-<50%; 50-<75%; 75-100%	0.25 – 1

Some of the factors used to assess exposures have been previously used to reconstruct past exposures and have been shown to be important predictors of exposure levels in the non-construction settings [68, 69]. The magnitudes of the levels for each factor was determined subjectively by simply ranking the levels and assigning increasing scores for factors related to increasing exposures and decreasing scores for factors associated with lowering exposures. The final exposure for each operation/task for each specialty is a semi-quantitative score, obtained by multiplying the scores for each factor. The maximum score range is from 0-16. Since the scores for the factors are multiplied, the contribution of each additional factor to the score is non-linear. Therefore, scores of 1-<3 can be classified as Low, 3-<6 as Moderate and ≥6 as High. Exposures were assessed for respirable dust, silica, wood dust, welding fumes, diesel exhaust and man-made mineral fibres (Table 8 at the end of the report). It represents a framework for classifying carpenter's work into specialties and identifying tasks, time in tasks, tools and materials used, types and levels of exposure and the determinants of exposure associated with tasks within the specialties. The new simplified matrix includes operation/task as its central element of analysis, and was used to assess the probability of exposure to agents identified for tasks and specialties.

The results of that survey show a range of exposure scores for the respirable dust as well as some variation for the other agents when the source is present. Since exposures depend on source material, whenever there was a potential for a source material to be used, it was assumed to be present. For example, fiberboard could be used in finishing and framing operation/tasks, so it was assumed to be present. The range of exposure score for the respirable dust among the specialties suggests that the proposed case control study is feasible.

One of the principal objectives of this study was to develop a database of union carpenters potential exposures and levels associated with the different specialties, operation/tasks and other determinants of exposure. Table 8 presents this information for exposure to respirable dust, silica, wood dust, diesel exhaust and MMMF.

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Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
Foundation work	Formwork	Build footing forms	Cut or saw Bore holes Fit forms	Cutoff saw, hammer drill,	Plywood, lumber, form oils	Wood dust, oil mist/s	Open	Excav/Trench/backfill/grade; Power generators; Mix & Pour concrete; Cure concrete; Rough plumbing PVC pipes cleaner/ cement;	Diesel,PNOC; Gas/Diesel; Cement dust, concrete/s; Benz, Tol, Xyl, TMB, Stod solv; MEK, acetone, tetrahydrfuran, cyclohexanone, toluene, PNOC
			Strip forms	Pry bars, hammers	Concrete, plywood, lumber	Silica, PNOC, oil mist	Open		
		Build foundation walls, columns, posts, pier forms Build slab foundation, basement or surface floor, driveway	Cut or saw Bore holes Fit forms & Erect forms	Cutoff saw, hammer drill,	Plywood, lumber, Concrete, form oils, polystyrene, prefabricated forms,	Wood dust, plastic dust, oil mist/s, PNOC	Open		
			Strip forms	Pry bars, hammers	Concrete, plywood, lumber	Silica, PNOC, oil mist	Open		
		Build forms for bridges, tunnels and other structures	Cut or saw Bore holes Fit forms	Cutoff saw, hammer drill, OA torch	Plywood, lumber, Concrete, form oils, polystyrene, prefabricated & steel forms	Wood dust, plastic dust, oil mist/s, PNOC, metal dust and fumes	Open		
			Strip forms	Pry bars, hammers	Concrete, plywood, lumber	Silica, PNOC, oil mist	Open		
		Waterproof and Insulate basement walls	Apply waterproofing	Mop, sprayer	Liquid asphalt waterproofing	Benz, tol, asphalt, stod solvent	Open		

Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
			Apply insulation & seal & cure concrete	Hammer, brush, sprayer	Fiberglass insulation Polyurethane sealant	MMMF MDI, EB, xyl, stod solv,	Open		
	Piledriver	Install/guide piles		Hammers, welding machines, boring augers	Steel (H, pipe, caisson, reinforced, sheet), Concrete, Timber, Composites, PT woods	PNOC, silica, diesel, welding fumes, creosote, CCA, chlorophenols (dump material)	Open	Excav/Trench/backfill/grade; Power generators; equip, trucks Mix & Pour concrete; Cure concrete; Cut drill concrete, wood piles	Diesel,PNOC; Gas/Diesel; Cement dust, concrete/s; Benz, Tol, Xyl, TMB, Stod solv Silica, PNOC, wood dust
		Splices and butt welding		Welding machine		Welding fumes, metal dust	Open		
		Drill concrete	Drilling, cutting, chipping	drill		Silica, PNOC	Open		
		Pre boring					Open		
		Underwater diving				None			
		Demolition and removal work		Abrasive wheel, torch cutting,		Silica, PNOC, diesel, welding fumes, lead, metal dust	Open		
Frame construction	Framing	Floor framing-Install beam (girder), bearing posts, joists and sill plates			PT wood, Heavy timber, lumber,	Wood dust, Cr, Cu, As, Chlorophenols	Open.		

Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
		Floor framing-Install, glue sub-floors			Plywood, OSB sheathing, Chalk Construction adhesive;	Wood dust; Silica Tol, n-hex, etOH, alipHC, xyl, EB, Std solv, MDI;	Open		
		Wall framing-Install studs, construct walls and partitions (sheathing)			Lumber, plywood sheathing, home wrap	Wood dust	Partial		
		Roof framing-Install ceiling joists, ridge board and rafters			Lumber	Wood dust	Partial		
		Roof framing-Install roof trusses and sheathing			Lumber, plywood	Wood dust	Partial		
		Stairs building-Install stringer, risers and treads, handrails and posts			Lumber	Wood dust	Enclosed		
		Build decks and porches			Pressure treated wood	Wood dust, Cr, Cu, As, Chlorophenols	Open		
		Scaffolding, ladders and hoists			Lumber	Wood dust	Open		

Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
	Form work	Concrete structural framing			Concrete			Concrete frame Steel frame welding, cutting Masonry wall	Silica, PNOC Welding fumes, Metal dust Silica, PNOC
	Ironworker	Steel structural framing			Steel				
Exterior finishing	Framing	Cornice work and gutters					Open	Concrete finishing	Silica, PNOC
	Roofers	Roofing	Apply waterproofing Apply shingles	Asphalt, HC, min spirits	Wood, Al, Asb, Asphalt, shingles, tar, tiles, rolled, poured		Open		
	Framing	Fitting doors and window frames			Silicon, caulk	TMB, xyl,	Open	Concrete finishing	Silica, PNOC
	Framing	Applying exterior finishing (barriers paper, trim and siding)			Gorilla glue, polyurethane glue		Open	Brick finishing Glass finishing Masonry mixing Concrete finishing	Silica Glass dust Silica, PNOC
Interior finishing	Insulation	Insulation & fireproofing	Seal gaps	Sprayer, blower	Polyurethane foam seals	MDI	Enclosed		
			Spray on insulation	Spray, Install	Fiberglass insl Sil acryl caulk	MMMF Eth glycol			

Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
	Drywall, blue board and plasterers	Finish wall	Hang drywall Apply joint cmp Sand joint comp Mix plaster, apply plaster	Rotor zip, saws, drills,	Gypsum board, plywood, plaster,	PNOC, silica, MMMF, Acetone/s	Enclosed L exhaust	Insulation; Fireplace & chimney; Rough plumbing PVC pipes and copper pipes;	MMMF PNOC, silica MEK, acetone, tetrahydrfuran, cyclohexanone, toluene, PNOC, ZnCl,NH3Cl, Cu, Ag, Sb, Sn
	Ceiling	Install ceiling	Grid wire installation, shooting wire	Saws, drill, nailer,	Acoustical tile,	MMMF, PNOC,		HVAC insulation	MMMF
	Floor finishers	Lay floors		Buffer, Sander, kicker,	Wood floor; Ceramic tiles; Vinyl flooring; Polyurethane finish Rubber tiles Linoleum Carpets	Wood dust, PNOC, solv... Eth glycol, tol, xyl, stod sol, silica MDI Stod solv. Epoxy adhesives	Enclosed	Insulation Cleaning floor Painters Drywall dust	MMMF Silica, PNOC, MMMF Tol, xyl, isobutanol, stod solv, MEK, isopropanol, benz, ethylene glycol Silica, PNOC
		Remove old floors			Asb. tiles	Asbestos			
		Floor leveling			Fine cement	Silica, PNOC			
		Floor cleaning			solvents	solvents			

Table 6: Construction Carpenters (Residential, Commercial, Road & Highway, Bridge, Tunnel and Other Structures)									
Stage	**Specialty**	**Operation**	**Tasks**	**Tools**	**Material**	**Exposures**	**Workplace Enclosure**	**Bystander Activities**	**Exposures**
	Finish work	Interior trim, baseboard and molding			Wood, composite mat	Wood dust, PNOC	Enclosed	Insulation Painters	MMMF Tol, xyl, isobutanol, stod solv, MEK, isopropanol, benz, ethylene glycol
	Finish work / fixtures	Doors and windows		Saws, drills, nailer,	Caulk, seam seals, lacquers	TMB, xyl, Wood dust,	Enclosed		
	Finish work / fixtures	Closet shelving	Cutting Sanding	Saws, drills, nailer,	Glue Wood, laminates, composite mat	Acetone, hex, tol Wood dust, PNOC	Enclosed		
	Finish work / fixtures	Kitchen Cabinets and counter tops	Cutting Sanding Installing	Saws, drills, nailer,	Glue Wood, laminates, composite mat	Acetone, hex, tol Wood dust, PNOC	Enclosed		

Table 8: Semi-Quantitative Particulates, Fumes and Solvents Exposures Associated with Specialties and Operation/Tasks in Construction Carpentry								
Specialty	**Operation/Task**	**RD**	**WD**	**SI**	**WF**	**DE**	**MF**	**SO**
Formwork	Cut, saw, bore holes and drill forms	12	12	3	-	6	-	4
Formwork	Fit and assemble forms	4	4	3	-	6	-	4
Formwork	Strip forms	8	4	4	-	6	-	4
Formwork	Apply waterproofing	8	-	3	-	6	-	24
Formwork	Apply insulation & seal, cure concrete	4	-	3	-	6	12	8
Pile driving	Install/guide piles	4	-	3	6	12	-	4
Pile driving	Splices and butt welding	12	-	3	12	12	-	4
Pile driving	Cut and drill piles	16	-	8	6	12	-	4
Pile driving	Pre boring/drilling	12	-	6	6	12	-	4
Pile driving	Demolition and removal work	16	-	8	6	12	12	-
Framing	Install framing (floor*, wall, ceiling, roof)	24	24	-	12	-	24	2
Framing	Install sheathing	24	24	-	12	-	24	-
Framing	Build decks and porches	12	12	-	-	-	-	-
Framing	Build scaffolding, ladders and hoists	12	12	-	-	-	-	-
Framing	Fitting windows and doors	4	4	-	-	-	-	-
Framing	Applying exterior finishing (trim, siding, cornice and gutters)	12	12	-	-	-	-	1.5
Insulation	Spray or blow foam insulation	36	-	-	-	-	36	4.5
Insulation	Smoke sealing	6	-	-	-	-	6	1.5
Insulation	Install insulation batts	12	-	-	-	-	12	1.5
Drywall	Hang drywall	24	-	12	-	-	-	3
Drywall	Apply joint compound or plaster	12	-	6	-	-	-	1.5
Drywall	Sand joint compound or plaster	48	-	24	-	-	-	6
Ceiling	Installing ceiling	12	-	6	-	-	36	1.5
Floor layers	Remove old floors	24	12	12	-	-	-	3
Floor layers	Floor cleaning	24	24	12	-	-	24	3
Floor layers	Floor leveling	48	48	24	-	-	-	6
Floor layers	Troweling and lay floors	12	-	-	-	-		1.5
Finish	Interior trim and molding	36	36	-	-	-	18	4.5
Finish	Interior fixtures (doors, windows, closet, shelving)	24	24	-	-	-	18	3
Finish	Kitchen cabinets, countertops and shelving	24	16	-	-	-	18	3
Scaffolding	Build scaffolding	12	12	3	6	6	-	1.5

RD: Respirable Dust; **WD:** Respirable Wood Dust; **SI:** Respirable Silica; **DE:** Diesel Exhaust--Fumes; **WF:** Respirable Welding Fumes; **MF:** Respirable Man Made Mineral Fibers; **SO:** Solvents