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# An Asbestos Job Exposure Matrix to Characterize Fiber Type, Length, and Relative Exposure Intensity

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**The relationship between asbestos exposure and disease has been well documented, although questions persist as to variation in risk by the type and length of fiber. For a series of jobs with potential asbestos exposure, the primary fiber type (e.g., amosite, anthophylite, chrysotile, crocidolite, or tremolite) and fiber length were identified and the relative exposure intensity was estimated. The resulting job exposure matrix may be useful in epidemiological studies where asbestos is an exposure of interest.**

**Keywords** Asbestos, Fiber Type, Fiber Length, Exposure Intensity

Exposure to asbestos has been associated with an increased risk of adverse health effects in a number of populations especially since the early 1960s.[1–6] In addition to employment as an insulator or shipyard worker,[7–10] exposure may occur in a wide range of other industries.[11–17] Nicholson et al.[18] provided a detailed listing of occupations where workers may be exposed to asbestos. Work activities and jobs reported to involve asbestos exposure include a range of duties, such as laborer, supervisor, and handyman that may be conducted in industrial and non-industrial settings.[19–24]

Evidence from some reports suggests that the risk of disease and the latency may vary depending upon the type of asbestos fiber exposure and length.[25–34] In animal experiments, diameter and length of inhaled fibers have been shown to be important determinants of the site of deposition and subsequent translocation.[35–37]

No job exposure matrix (JEM) was identified that included information on exposure intensity and asbestos fiber type and length. Thus the work presented was undertaken to provide a link between job title or activity reported in a work history and the type and length of asbestos fibers that could present a potential for exposure. The JEM was developed for exposure assessment for an epidemiologic study.

## METHODS

Potential asbestos exposure situations were grouped broadly into primary or secondary use in product manufacture, ship-related occupations, mining and milling, and end-user/maintenance activities.[18] Industries or jobs associated with potential asbestos exposure were listed within each of these groups. Primary or secondary manufacturing industries cover a gamut of products, including friction products, paints and sealants, and electrical appliances. Among ship-related occupations, several groupings are relevant. First are those jobs with potential for direct contact with asbestos, for example, welder or electrician. Bystander occupations, in which employees might receive exposure as a result of the work conducted by tradesmen using asbestos-containing materials can also be identified.[38,39] One group of bystanders includes occupations that work routinely on or near the ship, for example, riggers. The second bystander group includes employees who might periodically go to the ship construction area, but work routinely in office areas adjacent to the yard.

A major component of the end-user/maintenance group is the building construction trades that are identified by craft; for example, carpenter, painter, tiler. Other end-user and maintenance job titles include activities that may bring a worker in contact with asbestos-containing products; these include elevator manufacture, installation, or repair; power generation; steam locomotive repair/overhall, and brake manufacture or repair. Exposure may occur during other types of work activities, such as inspecting

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buildings, fire fighting, or diamond cutting. Exposure may also occur through the use of products potentially contaminated with asbestos (e.g., industrial use of talc).

Literature sources were reviewed to identify the likely fiber types used for various applications and the relative lengths of the fibers.[7,10,40–48] The type of fiber was characterized as amosite, anthophylite, chrysotile, crocidolite, or tremolite. Many uses of asbestos involve more than one fiber type; for example, thermal pipe insulation frequently contains amosite and chrysotile fibers while reinforced plastic may contain chrysotile, crocidolite, and amosite. Thus, the JEM was constructed to include multiple types of fibers, as appropriate.

The type and length of fiber were inferred for operations in which products containing asbestos were used. For example, from the documented use of chrysotile and amosite in building construction and pipe insulation, the potential for exposure to these fibers during building demolition was inferred. Similarly for building renovation activities, potential exposure to tremolite and anthophyllite was inferred because of the presence of these fibers in drywall materials. When potential exposure resulted from use of a product containing asbestos, fiber length was assumed to be equal to that in the original product.

For intensity during the period of exposure, a four-level scale was developed: very low, low, moderate, high. Very low was considered below the limit of detection using phase-contrast microscopy;[48] low was assigned for exposures likely to be above the limit of detection but below 2 fibers/cc (f/cc); medium, 2–7.9 f/cc; and high, 8 or more f/cc, during the measurement period. The extensive compendium of exposure levels reviewed by Nicholson et al.[18] was used as benchmark values. The inclusion of a category for very low–exposure jobs/activities allows evaluation of the potential effects of work in many occupations that might otherwise be excluded, such as building inspection and sale of asbestos-containing materials such as floor coverings, where cutting would be unlikely to result in detectable concentrations of airborne fibers. For these low-exposure jobs, potential contact with an asbestos-containing material was required.

## RESULTS

Jobs with potential asbestos exposure included in this JEM, and fiber types and lengths are shown in Table I. Definitions for the abbreviations and symbols are given in the key at the end of the table and summarized here. Fiber length for chrysotile is shown as grade, with Grade 3 being the longest and Grade 7 the shortest. Amosite and crocidolite are characterized as extra long, long, medium, or short. No length data were found for tremolite or anthophylite.

The four-point scale for relative exposure intensity is shown as 1 (very low) to 4 (high) for most jobs; for a small number of jobs, the letter D is listed, indicating that the duties performed by a person with this job title could result in exposure from none to high, depending upon the activities conducted. For example, construction work not-otherwise-classified (NOC) would be used for a project manager. If the work involved purchasing of material at distribution centers, the job would be assigned to category 1 (low); if the job involved onsite oversight of overhaul of an insulation-clad boiler in 1955, exposure would be assigned to category 3 (medium).

A wide variety of industries and operations associated with potential exposure are listed. The majority of jobs were included in the a priori list; those added during the review of the work records from the epidemiology study were milling or other use of talc, shipyard painter, shipyard mechanic/machinist, train engineer, building inspector, longshoreman, renovation, use of asbestos products NOC, sale of asbestos products NOC, and ironworker. Examples of jobs associated with the "use of asbestos products, NOC" included laboratory technician and household appliance repair; the category "sale of asbestos products, NOC" included workers in hardware, plumbing supply, automotive supply, and flooring businesses. For these activities, the fiber type is listed as "variable" to allow for assignment using more specific information in the work history; for example, the specific product used, sold, or repaired might be available in the history.

## DISCUSSION

Calendar dates were not included in the JEM; however, use requires some historical perspective. The numbers of employees in each of these industry sectors has changed over the years as the use of asbestos rose and fell. Approximately 66,000 metric tons were used in the United States in 1910, increasing to 300,000 metric tons in 1940 and, by 1950, use had more than doubled to 700,000 metric tons, in part reflecting shipyard use.[42] Use peaked in about 1970, and has subsequently declined. A number of key dates are useful in evaluating the potential for asbestos exposure. For example, insulation work was an established skilled trade in the early part of the century, when a New York local joined others to form the Asbestos Workers Union.[2] The years of spray application as a fireproofing material on structural steel are 1958–1972.[18] During the 1950s, the change from steam to diesel locomotives decreased the numbers of persons exposed during roundhouse repair operations.[18] The dates of specialized uses of asbestos such as in cigarette filters can be documented.[50]

This JEM was developed for use with occupations held through the early 1980s reported by subjects in an epidemiology study; therefore, it does not include all possible jobs or exposure scenarios. Application to later dates should follow a review of the relative exposure intensities for relevance to the time period. Additional jobs or activities might be added to reflect changing uses of asbestos-containing materials. For example, asbestos abatement work tasks are not included here.

The exposure intensities are relative categories and are set arbitrarily. An exposure of 2 f/cc was recommended as the American Conference of Governmental Industrial Hygienists (ACGIH)® Threshold Limit Value (TLV)® for chrysotile in 1979.[51] Quantitative exposure assessment studies in the asbestos textile industry showed that quadrupling the endpoints of an exposure group resulted in statistically different means for

**TABLE I**

Product manufactured or job with potential asbestos exposure, length of primary fiber type(s), and relative exposure intensity

| Manufacturing sector/ product or job | Uses | Fiber type/length[A] | Relative exposure intensity[B] |
|---|---|---|---|
| Primary or secondary manufacturing industries | | | |
| Friction products | Clutch/transmission, brakes | Grade 7 C | 3 |
| | Industrial friction materials | | |
| Pipe | Chemical process pipe | Grade 4 C | 3 |
| | Water supply | L Cr | |
| | Conduits for electrical wire | | |
| Textiles | Roofing materials | Grade 3 C | 3 |
| | Fire/heat-protective clothing | | |
| | Dryer felts | | |
| | Electrical wire and pipe insulation | | |
| | Fireproof draperies/curtains | | |
| Tiles | Office, commercial, and residential applications | Grade 5/6 C | 3 |
| | | M A | |
| Roofing felts | Roofing felts | Grade 6 (5–7) C | 3 |
| Other building materials | Roof coatings | Grade 5/6 C | 3 |
| | Roof patching compounds | | |
| Paints/coatings/sealants | Auto/truck body coating | Grade 7 C | 3 |
| | Roof coating/patching compounds | | |
| Reinforced plastics | Electric motor components | Grade 3 C | 3 |
| | Hi-strength molded components | L Cr | |
| | | S A | |
| Gaskets, packing and sealing | Valve, flange, pump, tank assembly | Grade 3 C | 3 |
| Building paper/board | Paper: ducts, pads/mats | Grade 5/6 C | 3 |
| | Underlay for floor | L/M/S A | |
| | Beverage filter | | |
| | Appliance/electric insulation | | |
| | Gaskets | | |
| | Heat/fire protective | | |
| | Board: hoods/vents | | |
| | Chemical tanks | | |
| | Residential/commercial/ industrial buildings | | |
| | Molten metal handling equipment | | |
| | Fire protection | | |
| | Insulation | | |
| | Small appliance/electric motor components, | | |
| | Lab furniture, cooling towers | | |
| Heating boilers, domestic furnaces, burners | | Grade 3 C | 3 |
| | | EL/L/S A | |
| Boiler shops | | Grade 3 C | 4 |
| | | EL/L/S A | |
| Industrial furnaces/ovens | | Grade 3 C | 3 |
| | | EL/L/S A | |
| Electric housewares and fans | | Grade 3 C | 2 |
| Cigarette filter | | EL/L Cr | 2 |

*(Continued on next page)*

**TABLE I**
Product manufactured or job with potential asbestos exposure, length of primary fiber type(s), and relative exposure intensity
*(Continued)*

| Manufacturing sector/ product or job | Uses | Fiber type/length[A] | Relative exposure intensity[B] |
|---|---|---|---|
| Ship-related occupations | | | |
| Shipbuilding and repair, NOC | | EL/L/S A<br>Grade 3 C | 3 |
| Furnace/boiler maker | | | 4 |
| Welder/cutter/burner | | | 4 |
| Electrician | | | 4 |
| Plumbing | | | 4 |
| Mechanic/machinist | | | 4 |
| Bystander Group 1 | | | 3 |
| Joiners | | | |
| Riggers | | | |
| Sandblasters | | | |
| Fitters | | | |
| Shipwrights | | | |
| Painters | | | |
| Bystander Group 2 | | | 2 |
| Draftsmen | | | |
| Handymen | | | |
| Engineers | | | |
| Estimators | | | |
| Ship operation, NOC | | EL/L/S A<br>Grade 3 C | 2 |
| Engine room | | | 3 |
| Marine engineer | | | 3 |
| Mining and Milling | | | |
| Mining, asbestos | | Grade 5 C<br>T | 2 |
| Milling, asbestos | | Grade 3 C<br>T | 4 |
| Talc | | T, An (short) | 4 |
| End users/maintenance/asbestos as a contaminant | | | |
| Construction, NOC | | | D |
| General contractors | | Grade 5/6 C<br>EL/L/S A<br>T, An | 2 |
| Water, sewer, pipe | | Grade 4 C<br>Cr M | 2 |
| Welding/metal cutting | | Grade 3 C<br>EL/L/S A | 2 |
| Plumbing/heating (except electric) and cooling | | Grade 3 C<br>EL/L/S A | 3 |
| Electrician | | Grade 3 C<br>EL/L/S A | 3 |
| Carpenter/flooring | | Grade 3 C<br>EL/L/S A | 2 |
| Paint/paperhang/decorating | | Grade 5/6 C<br>T, An | 3 |
| Tile/floor/terrazzo | | Grade 3 C | 1 |

*(Continued on next page)*

**TABLE I**
Product manufactured or job with potential asbestos exposure, length of primary fiber type(s), and relative exposure intensity
*(Continued)*

| Manufacturing sector/ product or job | Uses | Fiber type/length[A] | Relative exposure intensity[B] |
|---|---|---|---|
| Elevator, NOC | | Grade 5/6 C<br>Grade 5/6 C<br>L/M/S A | D |
| Manufacture | | | 1 |
| Install/repair | | | 2 |
| Power generation, NOC | | Grade 3 C<br>EL/L/S A | D |
| Stationary engineer | | Grade 3 C<br>EL/L/S A | 2 |
| Maintenance | | | 4 |
| Fire fighter | | | 4 |
| Electric, gas, and combination utilities | | Grade 3 C<br>EL/L/S A | 2 |
| Train engineers | | Grade 3 C | 1 |
| Steam locomotive repair/overhaul | | Grade 3 C | 4 |
| Brakes, NOC | | Grade 3, 7 C | 3 |
| Manufacture | | | 3 |
| Vehicle repair/maintenance | | | 2 |
| Talc use | | T, An (short) | D |
| Skilled trades/maintenance, NOC | | Grade 3 C<br>EL/L/S A | D |
| Building demolition | | Grade 5/6 C<br>EL/L/S A | 3 |
| Renovation | | Grade 5/6 C<br>EL/L/S A | 3 |
| Use of asbestos products, NOC | | Variable | 2 |
| Sales of asbestos products, NOC | | Variable | 1 |
| Ironworkers | | Grade 5/6 C<br>EL/L/S A | D |
| Longshoremen | | Grade 3 C<br>EL/L/S A | 2 |
| Building inspection | | Grade 5/6 C<br>EL/L/S A | 1 |
| Sheetmetal | | Grade 5/6 C<br>EL/L/S A | 4 |
| Roofing/siding | | Grade 5/6 C<br>L/M/S A | 2 |
| Glass and glazing | | Grade 5/6 C<br>EL/L/S A | 2 |
| Jewelry soldering/diamond cutting | | Grade 5/6 C | 2 |
| Fire fighter | | Grade 5/6 C<br>EL/L/S A | 1 |
| Other, NOC | | Variable | D |

*Note:* The letter designation that follows is the usual fiber type (C = chrysotile, A = amosite, T = tremolite, An = anthophyllite, Cr = crocidolite).

[A]Grade refers to the usual length for chrysotile, 3 is longest, 7 is shortest. Amosite and crocidolite are designated by: EL = extra long; L = long, M = Medium, S = short. See references.[7,10,40–48]

[B]Range = 1 (very low) to 4 (high). D indicates that exposure levels are diverse and a value is assigned after review of the work record. Extended as described elsewhere.[18]

adjacent groups.[52] While no mean of the categories in this JEM can be calculated, the guidance regarding setting endpoints is a useful template; therefore, the value of 8 f/cc, or four times the exposure of the lower group, was used as the lower bound of the high exposure group.

Investigators who have quantitative data for some jobs held by subjects should compare those data with the categories provided here for the sampling period and adjust as appropriate. Because of the extensive sampling of asbestos exposures, it is likely that values outside the ranges cited here will be identified; higher or lower estimates should be incorporated according to the professional judgment of the user. It is also noted that the user must provide an exposure intensity estimate for jobs categorized as "D." For example, the end user category "skilled trades/maintenance, NOC" would include gasket removal activities by pipe fitters and machinists. Here literature would be used to document the intensity of exposure, depending upon the methods used for removal.[20,53,54] The assignment of fiber type (chrysotile) and length (long) inferred from the listing for gaskets, packing and sealing, in the primary or secondary manufacturing industries in the first part of the Table is consistent with data from Millette et al.,[49] who report difficulty in characterizing the long, thin chrysotile fibers by electron microscopy.

The summary of fiber types and lengths shown allows consideration of these exposure characteristics in analyses of epidemiologic data. For example, if sufficient subjects were available, one could compare risk of disease between those exposed to chrysotile and a mixture of chrysotile and amosite. Differences in risk due to fiber length may also be investigated with the data presented. Where insufficient numbers of study subjects are available for separate type or length analyses, documentation of the range of fiber types and lengths could assist in interpreting study results and in comparing results with previous reports. The listing of types of fibers is general, and exceptions could be identified by other investigators for specialized applications. The lengths given are for initial production, and some shortening may occur during use; comparisons between these generalized lengths and published studies may be useful for a particular application, especially in characterizing exposures to end-users.

Based on our experience with using the system, several changes might be considered that would increase its usefulness. The detail for types of exposure settings could be expanded, if the information were available from the work history interviews. For example, construction trades such as plumbers might be separated into those engaged in new construction and those providing renovation or remodeling services. Mining and milling activities could be expanded to include other commercial minerals where asbestos is either a by-product or a contaminant.

## CONCLUSIONS

We present a JEM for asbestos developed to categorize exposure situations reported in work histories collected for an epidemiological study. The combination of asbestos type, length, and relative exposure intensity have not previously been available in a single JEM. When used during review of work histories by individuals experienced in occupational epidemiology exposure evaluation, this characterization of asbestos fiber exposure may be useful in exposure reconstruction.

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