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Application of a Method to Evaluate the Quality of Work Histories and Document the Exposure Assessment Process

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Background *Review of work history records by industrial hygienists is an important component of many occupational epidemiologic studies. A number of factors may influence the hygienist, such as the quality of the data and his or her previous experience. As part of a case-control study of mesothelioma, a system was developed to capture data on several factors that can be considered in a review of work history information.*

Methods *The overall quality of the work history record was described by noting the completeness and the consistency of the information; for any potential exposures, the reviewer experience on which the decision was based and the relative quality of the information were categorized. Because of the potential for mesothelioma cases and their next-of-kin to have undergone rigorous questioning about previous asbestos exposure an evaluation of the knowledge of the respondent was included. The frequency and intensity of exposure were also evaluated.*

Results *Evaluation of 3,444 work records is described. The importance of data completeness in the overall evaluation of quality is shown; follow-up questions regarding specific work tasks provide information not elicited in the standard interview process. The use of the literature was an important resource to the reviewer. Asbestos was reported by the respondent as an exposure on 149 work records; of these, 111 (74%) were judged to represent an unusual level of knowledge for a next-of-kin respondent.*

Conclusions *The approach presented allows capture of information about data quality and experience of the reviewer in an epidemiologic analysis. The ratings of frequency and intensity of exposure allow exploration of differences in exposure–response analyses using various exposure metrics.* Am. J. Ind. Med. 44:94–106, 2003. *© 2003 Wiley-Liss, Inc.*

KEY WORDS: work history; data quality; next-of-kin interviews; information bias; occupational case-control studies

INTRODUCTION

In occupational case-control studies, interviews with subjects or surrogates are typically used to collect information on potential risk factors for the disease(s) of interest. The interview information may provide details about work experience at past employment sites or further details on work history or lifestyle factors not included in written records. Although many epidemiologic studies have been based on analyses using job title or duration of employment in the index industry, more recent efforts involve professional review by industrial hygienists or others familiar with

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occupational exposures and conditions in order to improve exposure assessment and decrease misclassification. In a study of work histories provided by subjects for the years prior to employment in the industry of study, Schmidt [1994] showed that review by experienced industrial hygienists added substantially to the understanding of potential exposures, compared with self-reports and the National Occupational Hazards Survey (NOHS) [1977] Job Exposure Matrix. Stewart and Stewart [1994] recommend that several factors be considered in such a review of occupational histories: consistency of information, familiarity of the industrial hygienist with the job/industry, and probability of exposure.

We report the development and implementation of an approach to the evaluation of several factors that can be included in a review of work history information that builds on the recommendations of Stewart and Stewart [1994]. Variables are defined for an assessment of the overall quality of the work history record, documenting the data elements used to make the exposure assessment, and the consistency of the information throughout the record for each job. Variables were also presented to capture the experience (familiarity) of the reviewer with the job, the knowledge level of the respondent, and the quality of information to evaluate each of the specific exposures. The numerical values assigned to experience, knowledge level, and quality of information were chosen arbitrarily for convenience only; character values could have been selected as an alternative. The probability, frequency, and intensity of exposure are recorded. Use of these variables in an epidemiologic analysis will be reported elsewhere. While the records used were from a case-control study of mesothelioma, the general approach can be applied to other series of work histories reviewed for exposure assessment.

METHODS

Work History Records

Data used for this exposure assessment were collected as part of a case-control study that included 208 cases (183 men, 25 women) diagnosed 1975–1980 and identified through the New York State or Los Angeles County Cancer Registries or through the files of 39 large Veterans Administration (VA) hospitals. The case diagnoses were confirmed as definite or probable mesothelioma after review of pathology; 183 cases were classified as pleural or pleural and peritoneal, and 25 cases were peritoneal only [Spirtas et al., 1986]. Deceased controls (428 men, 105 women) were identified from the catchment area of each registry and from deaths listed in the Beneficiary Identification and Records Locator Subsystem of the VA. Information was obtained from the next-of-kin during an extensive telephone interview designed to provide data for exploration of a number of hypotheses related to mesothelioma. Details about the entire questionnaire and study population demographics are given elsewhere [Spirtas et al., 1994; Heineman et al., 1996]. The interviews were completed between 1982 and 1984.

The work history portion of the questionnaire was designed to elicit information about each full- and part-time job held for at least 3 months after age 12. The recorded work history began at age 12 because these subjects left school to start employment at a very early age or held part-time employment during the middle and high school years. Reported job title, duties, name and location of company, type of business, materials used, and first/last years employed were recorded for each job. This standard block of questions was supplemented with a specified series of follow-up questions asked for each job. These included reported exposure to unspecified dust or chemicals, and nine activity- or industry-specific questions related to potential asbestos exposure. This latter group of asbestos-related activities included: brake lining installation or repair, furnace or boiler installation or repair, building demolition, plumbing or heating repair, insulation work, shipyard work, elevator installation or repair, textile production, paper production.

The entire work history was entered verbatim into a data base. The record for each job was displayed on a computer screen and reviewed by an industrial hygienist (CR), without knowledge of disease status. An example of the layout of the screen is shown in Figure 1. Only positive responses to the follow-up questions were displayed (e.g., in this example, furnace install/repair, and plumbing/heating repair). Asbestos-related exposure questions from other parts of the questionnaire [Spirtas et al., 1994] were not included in this report.

Reviewer input to the factors developed for the exposure assessment was shown in another portion of the screen, and the assigned values entered directly on each job record. Each of these variables is described below.

Variables to Describe Data Quality

An assessment of the overall quality of each job record included noting the completeness and consistency of respondent information, and the reviewer's opinion as to sufficiency of the information to evaluate at least one exposure. For completeness, the five work history block elements (e.g., job title, duties, name and location of company, type of business, materials used) and the follow-up questions shown on the work history screen were considered. The rating of completeness (0, 1) for each of the five work history elements included the requirement that the response was informative, for example, the datum was specific to the question and was useful in evaluating exposure. For example, given the job title ''plumber'' duties such as ''repaired household plumbing'' or ''installed piping in new construction'' were categorized as complete since the information was useful in understanding the job, however, entries such as ''don't know'' or ''helped

NCI MESOTHELIOMA Study Ver 1.0	
	ID: 104401
JOB TITLE: DK	
DUTIES: PLUMBING, FIXING THINGS, CLEANING	
NAME/LOC COMPANY: MOTHER & FATHER OWNED APARTMENTS CHICAGO, ILL	
TYPE OF BUSINESS: RAN AN APARTMENT BLDG.	
MATERIALS USED: PLUMBING TOOLS, DK WHAT ELSE	
YEARS WORKED: 1904-1914	HOURS WORKED: FULL TIME
FURNACE INSTALL/REPAIR: YES	
PLUM/HEAT REPAIR: YES	

FIGURE 1. Representation of the work history information screen for exposure assessment.

his father," were categorized as not complete because the information did not assist the reviewer in understanding the job duties of the study subject. All blank entries were rated as not complete. The follow-up question responses were categorized to denote report of unspecified dust or chemical exposure or seven of the nine activity/industries included in the interview as follow-up questions (manufacture of textiles or paper were judged to be less likely to reflect possible asbestos exposure than the other seven, and were excluded). The overall consistency of the work history block elements and the follow-up responses was evaluated (0, 1). A response which would be rated as inconsistent is illustrated by the following: duties, bookkeeper; type of business, bank; materials used, paper; follow-up response, plumbing/heating repair, yes. The duties and materials are consistent, but few if any bookkeepers employed at a bank are expected to perform plumbing/heating repair work at the work site. Finally, the combined work history block and follow-up responses were scored to indicate whether or not the reviewer found the information sufficient (0, 1) to evaluate the job for at least one exposure of interest.

Exposures Selected for Evaluation

An a priori list of exposures possibly related to the development of mesothelioma was developed by one of the authors (EFH) based on a MEDLINE search with the keyword mesothelioma supplemented by literature collected previously on mesothelioma, asbestos, and other putative risk factors. These exposures were then evaluated further using science citation index, ISI Web of Science. Secondly, we considered the whether the exposure was work-related and the feasibility of assessing exposure to an agent based on the available work histories.

In addition to asbestos, human and/or animal data supported inclusion of man-made synthetic vitreous fibers (MMVF), silica and silicon carbide manufacture [McDonald et al., 1970; Stanton and Wrench, 1972; Stanton et al., 1977; Brenner et al., 1982; Hirsch et al., 1982; Pott et al., 1987; Mast et al., 1995, Roller et al., 1996; Vaughan and Trently, 1996; Lentz et al., 1999; Miller et al., 1999; Bouchardy et al., 2002]. The possible relation between ionizing radiation and mesothelioma has been identified in human [Brenner et al., 1982; Antman et al., 1983; Gilks et al., 1988; Gold and Kathren, 1998] and animal studies [Warren et al., 1981; Hahn and Lundgren, 1992; Sanders, 1992]. Organic solvents and dyes, inks, and pigments were included due to the observed increased risk of mesothelioma in the shoe industry and among painters, textile, and leather workers [Decoufle, 1980; Englund, 1980; Brenner et al., 1982; Engholm and Englund, 1982; Roggli et al., 1982]. Among Danish printers, a trade with potential exposures to solvents and inks, a 50%

increased risk of pleural tumors was not statistically significant [Lynge et al., 1995]. Polycyclic aromatic hydrocarbons (PAHs) were included based on reports of animal experiments with methylcholanthrene [Warren et al., 1981] and benzo(a)pyrene [Pott et al., 1987]. Rats exposed by inhalation to methylene chloride have higher rates of mesothelioma than controls [NTP, 1986].

Several metals were identified. Chrome compounds induced mesotheliomas in animals [Hueper and Payne, 1959; Payne, 1960] and mesotheliomas have been reported in cohorts of chromate [deMarco et al., 1988] and ferrochromate [Axelsson et al., 1980] production workers. A case-control study in Canada reported mesothelioma in workers exposed to nickel and copper [McDonald et al., 1970]. Nickel and its compounds are carcinogenic in rats [Heuper, 1952; Pott et al., 1987]. A relation between mesothelioma and beryllium has been suggested in a case report [Oels et al., 1971].

Mesothelioma has developed in animals following exposure to ethylene oxide [Snellings et al., 1984], polyurethane [Hueper, 1960, 1964], and polysilicone [Hueper, 1959]. Mesothelioma has been reported among employees in the petrochemical industry [Hanis et al., 1982, 1985a,b; Roggli et al., 1982; Bertazzi et al., 1989; Mehlman, 1991; Giarelli et al., 1992; Rushton, 1993; Gennaro et al., 1994, 2002; Finkelstein, 1996; Huebner et al., 1997]. Rubber and tire manufacture have been identified as potential risks in case-control studies in Canada [McDonald et al., 1970] and the US [Teta et al., 1983].

Several agents unlikely to be found in the occupational setting were excluded, for example, RNA virus, MC29 avian leukosis virus [Chabot et al., 1970], SV40 [Cicala et al., 1993]. We considered but excluded other occupational exposures: biogenic silicates [Malker et al., 1983; Sinks et al., 1994], diethylstilbestrol [McClure and Graham, 1973], and mineral oil [Hirsch et al., 1982]. Three exposures linked to mesothelioma in animals [Peterson et al., 1984]—sterigmatocystin (a dietary mycotoxin), TMCA (constituent of wood lignins), and aluminum—seemed unlikely to be assessable in the occupational histories. We did not assess wood dust (as a surrogate for TMCA), although carpenters had increased risk of pleural tumors in the PMR study in England and Wales [Coggon et al., 1995]. The relatively new synthetic aramid fibers were also not included [Lee et al., 1983]. See Ilgren and Wagner [1991] and Pelnar [1988] for further compendia of agents or conditions found to be related to mesothelioma in animals or humans.

The final listing follows: asbestos, MMVF, ionizing radiation, organic solvents, dyes/inks/pigments, siliceous dusts, PAHs, metals, ethylene oxide, silicon carbide manufacture, leather industry, oil/petrochemical, rubber/tire manufacture, textile manufacture (excluding asbestos and MMVF), dry-cleaning, aircraft manufacture, plastics, metal machining, tool sharpening/grinding. The industries and processes were included in order to capture complex work environments representing several exposures of interest; for example, the oil/petrochemical industry might include exposure to asbestos, manmade vitreous fibers, organic solvents, metals, PAHs, and ionizing radiation depending upon job duties or work location.

Variables to Document the Exposure Assessment Decision Process

Definitions and codes developed for each of the exposure assessment factors are shown in Table I and described below.

Information source used to assess exposure

For each exposure, two variables were created to describe the source of the information used to make the exposure assessment decision. One was used to identify whether the work history block information, the follow-up questions, or both sources contributed to the assessment of possible exposure. The second variable characterized whether the follow-up question(s) was consistent with the work history elements, but did not add new information,

TABLE I. Definition and Possible Values of Factors Evaluated for Each Exposure Rated in the Work History Record

Factor	Value	Definition
Information source		
Data elements	1	Work history block question only
	2	Follow-up question only
	3	Both block and follow-up
Follow-up questions	0	No response/not relevant
	1	Consistent with work history block
	2	Adds information to work history block
	3	Inconsistent with work history block
Experience of reviewer	4	Direct: conducted IH survey, walkthrough or research project
	5	Indirect: discussed with colleague who has direct experience or personal experience with similar industry
	6	Literature documentation only
Knowledge of respondent	0	Exposure not mentioned
	1	Exposure mentioned and considered reasonable by reviewer
	2	Exposure mentioned and considered unusual knowledge by reviewer
Usefulness in evaluating		
Specific exposure	1	Minimal
	2	Fair/good
	3	Very good

added information, or was inconsistent. These two variables summarize the source of information used by the reviewer, and the contribution of the responses to follow-up interview script questions; values are shown in Table I.

Experience of reviewer/familiarity with job

Because of the diversity of jobs and employers reported in a large, multi-state study, it is impossible for any one or small number of reviewers to be familiar with working conditions in each company or industry; therefore, a variable was included to capture the experience on which the reviewer based the decision. Three categories of reviewer experience were defined, as shown in Table I: direct experience, indirect experience, literature reference only. As a reminder to the reviewer of need for literature resources or to contact colleagues, a notation was made on the screen to flag the need for follow-up action to obtain additional information. As the new information was obtained to complete an evaluation of exposure, the reviewer experience variable was entered, and the flag notation removed. Literature sources for this project included the Kirk–Othmer Encyclopedia of Chemical Technology [Kirk and Othmer, 1980; Grayson, 1987–1984; Kroschwitz, 1991–1995], Thomas Register of American Manufacturers and Thomas Register Catalog File [1940, 1960, 1965, 1970], Clinical Toxicology of Commercial Products [Gleason, 1957, 1963], and historical issues of the Journal of Industrial Hygiene and the Archives of Industrial Hygiene and Occupational Medicine. Specialty texts available from large libraries were also referenced (see Frazee, 1955 for early auto body repair methods).

Knowledge of respondent

Case-response bias must be considered in occupational studies, since cases or next-of-kin may have a higher level of information about potential exposures that could have contributed to disease development, compared with relatives of those free of disease. As each record was reviewed, notation was made as to whether the respondent mentioned the exposure being evaluated, if mentioned, the reviewer evaluated whether the level of respondent knowledge appeared reasonable, for example, was the information likely to have been reported during questioning by health care or other professionals after the diagnosis of disease. For example, among the exposures included in the dyes/inks/pigments group was paint. An exposure to paint might be listed in a description of materials with which a construction worker, painter, remodeler, or decorator worked. An example of unusual knowledge for a next-of-kin respondent (interviewed in 1982–1984) would be a reported asbestos exposure reflecting the subject's service on a ship as a deck hand for 2 years in World War II.

Usefulness of Information to Evaluate Specific Exposure

A job description may provide better information to evaluate one exposure than another. To evaluate whether the work history was more useful for evaluation of some exposures than others, the information was rated for each exposure, as very good, fair/good, or minimal. The variable supplemented the overall quality rating and captured differences in usefulness of the single work history to rate the 19 different exposures. For example, consider the following work record: job title, engineering department; duties, don't know; name/location, oil company in California; type of business, refine crude oil shipped in; materials used, don't know. The usefulness of the information to evaluate exposures to radiation, for example, is rated at ''minimal;'' however, for employment in the oil refining/petrochemical industry, the rating is ''very good.''

Exposure Probability, Frequency, and Intensity

In order to categorize the probability that the study subject was exposed, three benchmarks were developed: low, 30% or less; moderate, greater than 30 and less than 70%; high, 70% or greater. Based on the work history information and reviewer knowledge of the industry, the probability of exposure was estimated and then categorized into the appropriate group.

For any job assigned a probability of exposure, the frequency of exposure was evaluated. The values of frequency of exposure were defined as: daily constant, daily intermittent, weekly, monthly, quarterly/semiannual, less frequently/rare. This six-value range of frequency codes was selected to allow categorization of both routine and very infrequent activities, and was assigned for each exposure based on the specific information given by the respondent. Intensity of exposure was described on a four-level scale for asbestos (very low, low, moderate, high). Roughly, very low was considered below the limit of detection using phase-contrast microscopy [NIOSH, 1989], low was assigned for exposures above the limit of detection but below 2 fibers/cc (f/cc), medium was assigned for exposures from 2 to 7.9 f/cc, and high was assigned for exposures for 8 or more f/cc during the measurement period. The time-specific compendium of exposure levels reviewed by Nicholson et al. [1982] was used as benchmark values, since his references covered the employment years of these study subjects. 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. This category also allows

higher confidence that very low-level exposure had been considered.

RESULTS AND DISCUSSION

A total of 3,444 work records were reviewed for the 741 study subjects. Of these, the next-of-kin reported no employment ever for 11 individuals. The results for each factor evaluated are presented below, followed by discussion.

Variables to Describe Data Quality

The percent of each work history element completed with useful information follows: job title, 88; duties, 90; company name and/or location, 97; type of business, 90, materials used, 81. For 69% of the records, all five elements were completed with useful information. Duties, name of employer/location, and type of business were provided in 82% of the records. Job title, duties, and materials were available from 74% of the records.

Overall, 94% of the work records were judged to be sufficient for evaluating at least one exposure. The completeness of information elicited by the interviewer was strongly associated with the industrial hygiene reviewer's evaluation of ''sufficient.'' The percentage of work history records categorized as ''sufficient'' decreased monotonically as the number of elements completed with useful information at the interview decreased from five (all elements completed) to zero (100, 99, 85, 35, 17, and 0%, respectively). Of work history records with completion of three elements, notation of duties, company name/location, and type of business was the most informative combination for the reviewer, resulting in 2,809 (82%) records classified as sufficient. When job, duties, and materials were the three elements recorded, 2,533 (74%) records were categorized as sufficient. Direct interviews with study subjects are preferred to next-of-kin information. Cases for this project were diagnosed 1975–1980 and were generally not available to be interviewed. Therefore, only next-of-kin could provide the work history. These data could be analyzed to determine if the relation who provided the work history affects the completeness or usefulness; for example: Do spouses provide more complete information than a child? The relationship between the respondent and the subjects was not included in the work history data set.

The evaluation and rating for these variables may vary among hygienists reviewing work history records. While the absence of any response to a data element is easily identified as incomplete, the categorization of a response considered to be uninformative may be less clear. For example, the listing of paint as a material used for a painter, might be considered uninformative by a reviewer and categorized as incomplete information. As reported here, however, the entry would have been categorized as complete, since a consistent (informative) response was recorded. A refinement to this scheme might include a scale to rank the level of information each reported datum adds to the reviewer's knowledge of the potential exposures, for example, nothing, some, substantial.

Variables to Document the Exposure Assessment Decision Process

Information source used to assess exposure

In the 3,444 work records, a probability of exposure greater than zero was assigned to 5,023 exposures. The follow-up questions were not answered positively (n = 2,177) or provided no additional information to understanding the reported job (n = 1,827) for a total of 80% of the assessed exposures. The follow-up questions were targeted to unspecified dust and chemicals or asbestos-related activities; therefore, this low percentage of useful response is not surprising.

For 800 records (16%), the follow-up questions enhanced the information recorded in the work history block elements. For 209 records (4% of 5,023), the follow-up response was judged to be inconsistent with the work history information. For example, for the bookkeeper described above who also reportedly did plumbing and heating repair, a positive assessment of asbestos exposure would be made, with notation that the decision was made only on the follow-up questions and that the follow-up response was inconsistent with the work history block elements. One hundred sixty six of the 209 assessments (80%) based on inconsistent information related to three agents—asbestos, n = 52; solvents, n = 28; PAHs, n = 86. The seven follow-up questions regarding potential asbestos exposure captured information on activities not usually included in routine job duties. Positive response to possible exposure to ''unspecified chemicals'' captured information to support an assessment of solvent or PAH exposure. By providing an exposure evaluation, but also indicating inconsistency, epidemiologic analyses can be conducted with and without metrics to describe exposure to the specific agent/industry/operation where apparently inconsistent information was elicited.

The work history block elements were the most used information in evaluating exposure. The percent of assignments based on the work history only ranged from 43% for solvents (428 of 995 records) to 100% of all assignments for tool grinding, ethylene oxide, and leather. Only for organic solvents were the follow-up questions alone a major contributor to the assessment (n = 448, 45% of the 995 records). For example, the respondent may have reported exposure to ''solvents'' in response to the general follow-up question on chemical exposure. A job title such as office worker would not necessarily indicate solvent exposure, however, notation in the follow-up questions of mimeograph solution would

add to understanding of the job. The combination of work history and follow-up questions formed the basis for as many as 38% of the exposure assessments of potential exposure to asbestos (347 of 912) or work in the dry-cleaning industry (5 of 13). Other exposures to which the combined information contributed to 10% or more of the assessments follow: MMVF, 36% (92 of 255); organic solvents, 12% (115 of 995), dyes/inks/pigments, 16% (43 of 268); siliceous dusts, 29% (117 of 404); metals, 13% (62 of 478); metal machining, 16% (17 of 105); oil/petrochemical, 11% (3 of 28); tire, 16% (2 of 13); textiles 29% (5 of 17); plastics, 21% (12 of 57). The follow-up questions added information used by the reviewer for non-asbestos exposures, as the activities in this series of questions often include use or contact with other agents of interest.

Experience of reviewer/familiarity with job

Three values were included for the experience of the reviewer: direct knowledge, indirect knowledge, literature reference. For the 5,023 exposures in this study rated to be possible by the reviewer, 40% were based on direct knowledge, 48% on indirect knowledge, and 12% on literature references. The numbers of assignments for each agent by reviewer experience are listed in Table II. The values shown are quite variable. For exposures to specific agents, the proportion assigned based on direct experience varies from 12% (PAHs) to 63% (dyes/inks/pigments and siliceous dusts). The reviewer has conducted limited sampling for PAHs, compared with more extensive knowledge of the latter two categories acquired during in-depth research projects. Indirect experience or literature sources were the primary bases for assigning oil/petrochemical, aircraft, and plastics industry exposures—all of which are relatively unfamiliar to the reviewer. From these data, the approach appears to allow discrimination between various types of experience on which one reviewer based judgments.

Review of one work history record could take several minutes, depending upon the number of potential exposures rated as possible; if an average of 5 min is assumed for each of the 3,444 records, nearly two person-months was devoted to record review. Approximately one person-month of effort was devoted to searching the literature for information on material use and exposures. Thus the use of the literature increased project time by 50%.

Follow-back contact with the respondent was not possible for this study, but has provided additional information

TABLE II. Number (%) of Exposures Assigned Based on Direct Experience, Indirect Experience, and Literature Reference From Review of 3,444 Records for 741 Subjects

	Number (%)			
Agent/industry/operation	**Direct experience**	**Indirect experience**	**Literature**	**Total**
Asbestos [411][a]	560 (61)	241 (26)	111 (12)	912
MMVF [175]	116 (45)	83 (33)	56 (22)	255
Ionizing radiation [56]	19 (24)	28 (35)	33 (41)	80
Organic solvents [426]	349 (35)	503 (51)	143 (14)	995
Dyes/inks/pigments [170]	169 (63)	93 (35)	6 (2)	268
Siliceous dusts [232]	255 (63)	112 (27)	37 (9)	404
PAHs [494]	154 (12)	1,023 (82)	75 (6)	1,252
Metals [254]	199 (42)	145 (30)	134 (28)	478
Ethylene oxide [6]	4 (57)	2 (24)	1 (14)	7
Leather [18]	14 (58)	10 (42)	0 (0)	24
Oil/petrochemical [18]	9 (32)	17 (61)	2 (7)	28
Rubber/tire [9]	2 (18)	5 (45)	4 (36)	11
Textiles [11]	16 (94)	1 (6)	0 (0)	17
Drycleaning [12]	13 (100)	0 (0)	0 (0)	13
Aircraft [67]	23 (23)	70 (71)	6 (6)	99
Plastics [42]	20 (35)	34 (60)	3 (5)	57
Metal machining [59]	55 (52)	45 (43)	5 (5)	105
Tool sharpen/grind [11]	11 (61)	7 (39)	0 (0)	18

MMVF, man-made synthetic vitreous fibers; PAHs, polycyclic aromatic hydrocarbons.

[a]Number of subjects with at least one exposure to the agent/industry/operation. No records were rated as possible exposure to silicon carbide manufacture.

in community-based [Gerin et al., 1985] and occupational studies [Stewart and Stewart, 1994]. Stewart et al. [1992] have also gathered additional information by contacting co-workers. These methods may supplement the experience and other resources available to the reviewer(s).

In the present study, no restriction was put on the number of surveys or walkthroughs conducted in order to claim ''direct experience;'' in fact, as defined here, direct experience through conduct of a research project did not necessarily require visits to industrial sites. For example, knowledge of mining and mineral processing technology and exposures were known to the reviewer in part from an industry-wide study of the North Carolina Dusty Trades [Rice et al., 1984], a large data base of more than 400 companies. A requirement of multiple work site visits has been suggested [Stewart and Stewart, 1994]. Some industries such as construction include diverse activities and are conducted in a range of settings; reviewer knowledge may differ across industry sectors. In other applications, a distinction could be incorporated to specify sectors of an industry. Data to evaluate the impact of reviewer experience on exposure ratings are needed. This would assist researchers in selecting reviewers and also assist in evaluating the generalizability of ratings by a single reviewer.

Knowledge of respondent

The results of categorizing the knowledge of the respondent are shown in Table III. Next-of-kin respondents (149) reported asbestos exposure for the subject; of these 111 (74%) were categorized as indicating unusual knowledge of the subject's work by the next-of-kin respondent. The reviewer was not aware of Workers' Compensation claims or legal action. Only five other types of exposures reported by respondents were judged to represent unusual knowledge by the reviewer: MMVF (4 of 255 jobs), organic solvents (11 of 995 jobs), dyes/inks/pigments (1 of 268 jobs), siliceous dusts (1 of 404 jobs), and metals (1 of 478 jobs). The type of industry was reported in 90% of the job records. As shown in Table III, a high proportion of respondents' reports of industry ''exposure'' (e.g., leather) are categorized as reasonable. This evaluation of ''reasonableness'' may be related to the experience of the reviewer; for example, a reviewer very familiar with the construction trades might conclude that a next-of-kin report of creosote exposure for pile drivers is reasonable, while someone with less experience might conclude that the knowledge was unusually detailed. The contribution of reviewer experience to evaluation of respondent knowledge should be investigated.

TABLE III. Distribution of Work Records for Which Each Listed Exposure was Rated as Possible; for Those in Which the Respondent Mentioned the Exposure of Interest, the Reviewer Evaluation of Respondent Level of Knowledge is Shown

	Number (%) of records scored as possible exposure			
Agent/industry/operation[a]	Not mentioned by respondent	Reasonable to IH	Judged unusual knowledge	Comment
Asbestos	763 (84)	38 (4)	111 (12)	
MMVF	240 (94)	11 (4)	4 (2)	For example, fiberglass
Ionizing radiation	68 (85)	12 (15)	—	
Organic solvents	889 (89)	95 (10)	11 (1)	
Dyes/inks/pigments	156 (58)	111 (41)	1 (1)	For example, paint, printing ink
Siliceous dusts	285 (71)	118 (29)	1 (<1)	For example, cement, coal dust
PAHs	1,195 (95)	57 (5)	—	For example, exhaust, tar
Metals	441 (92)	34 (7)	3 (1)	For example, copper
Ethylene oxide	7 (100)	—	—	
Leather	3 (13)	21 (87)	—	
Oil/petrochemical	8 (29)	20 (71)	—	
Rubber/tire	1 (9)	10 (91)	—	
Textiles	4 (24)	13 (76)	—	
Drycleaning	2 (15)	11 (85)	—	
Aircraft	3 (3)	96 (97)	—	
Plastics	17 (30)	40 (70)	—	
Metal machining	73 (70)	32 (30)	—	
Tool sharpen/grind	14 (78)	4 (22)	—	

[a]Total for each row equals that shown in Table II.

Usefulness of Information to Evaluate Specific Exposure

Overall, 94% of the work history records were categorized as including sufficient information to evaluate at least one exposure. However, when the usefulness of the information was considered by exposure, the data were quite variable; as shown in Table IV, from 43 to 100% of records were categorized as ''very good,'' depending upon the exposure. The low proportion of ''very good'' work histories to evaluate ethylene oxide exposure or employment in the tire industry is puzzling, but may result from lack of detail in job duties. For example, a work history of a hospital worker that specified ''unknown'' duties would be rated of poor quality to evaluate ethylene oxide exposure. Both exposures were rare in the data set, 7 and 11 records, respectively.

Inclusion of this type of variable in the data set will assist in selecting exposures for use in the epidemiologic analysis based on quality of information, or allow the analyst to control for data quality. It has been recommended that epidemiologic analyses be conducted separately using and then removing data rated to have poor quality [Stewart and Stewart, 1994]. The approach suggested here provides a method to quantify both the quality of the overall work history and the quality of the information to evaluate a specific exposure. In the absence of knowledge of the true work history and exposures, this may be useful information to incorporate into the epidemiologic analysis and to consider in interpreting results.

TABLE IV. Number (%) of Exposures Assigned According to Usefulness of Record for Evaluating the Specific Exposure

	Number (%) of records in each category		
Agent/industry/operation[a]	**Minimal**	**Fair/good**	**Very good**
Asbestos	61 (7)	155 (17)	696 (76)
MMVF	5 (2)	28 (11)	222 (87)
Ionizing radiation	6 (8)	9 (11)	65 (81)
Organic solvents	56 (6)	172 (17)	767 (77)
Dyes/inks/pigments	13 (5)	30 (11)	225 (84)
Siliceous dusts	17 (4)	71 (18)	316 (78)
PAHs	62 (5)	194 (15)	996 (80)
Metals	40 (8)	81 (17)	357 (75)
Ethylene oxide	1 (14)	3 (43)	3 (43)
Leather	3 (12)	3 (13)	18 (75)
Oil/petrochemical	1 (4)	9 (32)	18 (64)
Rubber/tire	2 (18)	4 (36)	5 (46)
Textiles	0	0	17 (100)
Drycleaning	0	3 (23)	10 (77)
Aircraft	14 (14)	23 (23)	62 (63)
Plastics	5 (9)	10 (17)	42 (74)
Metal machining	18 (17)	21 (20)	66 (63)
Tool sharpen/grind	3 (17)	0 (0)	15 (83)

[a] Total for each row equals that shown in Table II.

Exposure Probability, Frequency, and Intensity

The values assigned for probability and frequency of exposure to any of the 19 agents/activities in the 3,444 job records reviewed are summarized in Table V. The number of jobs designated with low probability of exposure is generally smaller than those judged to be associated with a medium exposure, and always smaller than the proportion assigned high probability. These results may reflect hesitancy by the reviewer to assign a low probability when there is uncertainty in exposure probability assignment. The exposure frequency values indicate that few exposures were classified as continuous throughout the day. Intermittent daily, weekly, or monthly exposures were assigned to the majority of jobs. The highest proportion of jobs associated with rarely occurring exposure was asbestos (18%) and ionizing radiation (26%), ethylene oxide (100%) and tool sharpening (22%). Rare asbestos and tool sharpening exposures might occur as a result of annual repair activities. Potential radiation exposure might occur during the infrequent replacement of sealed sources. Health care workers with general job assignments could, on rare occasions, be exposed to ethylene oxide. Estimated exposure intensity ranged across the scale.

The percentage of persons with at least one job associated with an exposure is the lifetime prevalence cited by Siemiatycki [1991] from his studies in Montreal. Comparison of data from the current report (Table II, number of 741 subjects with at least one exposure to agent) with those from Montreal shows a higher prevalence in this population for asbestos (55% for any asbestiform-mineral vs. 6% amosite and 17% chrysotile), glass fiber (24 vs. 5%) ionizing radiation (8 vs. 1%), and siliceous dusts (31 vs. 24%); the lifetime prevalence for PAHs (67 vs. 64%), ethylene oxide (1 vs. 0.1%), and plastic dust (6 vs. 5%) are nearly the same. Differences in definitions and population demographics likely contribute to the higher lifetime prevalence in the study group compared with the Montreal group. For example, we included any probability of exposure, while the Siemiatycki data included records categorized as representing probable and certain exposure, and excluded records categorized as possible. The mesothelioma population included the VA and Los Angeles, two groups with a potentially higher probability of military-related occupations, including shipbuilding, compared with Montreal. While interviews were conducted in the early 1980s in both populations, 23% of subjects in the present study were age 70 or greater, while no one in the Montreal study exceeded age 70. Since the identification of potential exposure was done without knowledge of disease status, any misclassification is likely to be non-differential

TABLE V. Summary of Probability and Frequency Assignments for 3,444 Jobs for Each of the Exposure/Activities Evaluated

	Number (%) of exposure probability			Number (%) of exposure frequency					
Exposure/activity (n)	Low	Medium	High	Rare	Quarterly seminannual	Monthly	Weekly	Daily/intermitent	Daily constant
Asbestos (912)	180 (20)	239 (26)	493 (54)	164 (18)	121 (13)	230 (25)	237 (26)	155 (17)	5 (1)
MMVF (255)	32 (12)	78 (31)	145 (57)	11 (4)	35 (14)	93 (37)	89 (35)	26 (10)	1 (4)
Ionizing radiation (80)	7 (9)	21 (26)	52 (65)	21 (26)	—	3 (4)	30 (38)	15 (19)	11 (14)
Organic solvents (995)	68 (7)	346 (35)	581 (58)	20 (2)	13 (1)	98 (10)	360 (36)	489 (49)	15 (2)
Dyes/inks/pigments (268)	34 (13)	79 (30)	155 (58)	22 (8)	16 (6)	108 (40)	68 (25)	50 (19)	4 (2)
Siliceous dust (404)	22 (5)	90 (22)	292 (72)	12 (3)	22 (5)	87 (22)	121 (30)	160 (40)	2 (1)
PAHs (1,252)	42 (3)	180 (14)	1,030 (82)	4 (<1)	44 (4)	95 (8)	206 (17)	902 (72)	1 (<1)
Metals (478)	50 (11)	130 (27)	298 (62)	24 (5)	13 (3)	87 (18)	222 (46)	132 (28)	—
Ethylene oxide (7)	2 (29)	2 (29)	3 (43)	7 (100)	—	—	—	—	—
Silicon carbide manuf. (0)	—	—	—	—	—	—	—	—	—
Leather (24)	—	4 (17)	20 (83)	—	—	—	—	—	24 (100)
Oil/petrochemical (28)	1 (4)	2 (7)	25 (89)	—	—	—	—	—	28 (100)
Rubber/tire (11)	—	—	11 (100)	—	—	—	—	—	11 (100)
Textiles (17)	3 (18)	—	14 (82)	—	—	—	—	—	17 (100)
Dry cleaning (13)	—	—	13 (100)	—	—	—	—	—	13 (100)
Aircraft (99)	13 (13)	15 (15)	71 (72)		—	—	—	—	99 (100)
Plastics (57)	6 (11)	9 (16)	42 (74)	—	—	—	—	—	57 (100)
Metal machining (105)	6 (6)	38 (36)	61 (58)	6 (6)	—	3 (3)	22 (21)	74 (71)	—
Tool sharpen/grind (18)	6 (33)	5 (28)	7 (39)	4 (22)	—	4 (22)	—	10 (56)	—

and bias any measure of exposure–response toward the null [Copeland et al., 1977].

In the previous report by Spirtas et al. [1994], several exposure variables were constructed. Using the job title and industry of employment, probability of exposure to asbestos was determined through the National Occupational Hazards Survey (NOHS) [1977]; 259 subjects were assigned a possible exposure to asbestos, compared with 441 in the current review. The direct question ''was the subject ever exposed to asbestos'' resulted in 219 positive responses, compared with the 149 who named asbestos as one of the materials the subject worked with in the detailed occupational history. Including the textiles and paper follow-up questions, 388 next-of-kin responded positively to at least one of these activities; this was considered an indication of asbestos exposure. Overall, using the above work-related metrics plus non-work related bystander and residential history, 524 subjects were categorized as exposed to asbestos in the previous analysis. The two evaluations were not be compared rigorously in this report; however, the details of the work history review presented here attributed asbestos exposure to more individuals than use of a direct question, NOHS or the activity list used as separate metrics; when these and non-occupational metrics were merged, a higher number of subjects were classified as exposed. These exposure metrics will be evaluated further in a future study.

The numerical values assigned to the variables are arbitrary and were selected for convenience only. For example, a value of 6 (literature documentation only) in experience of the reviewer is not ''better'' or ''bigger'' than a value of 4 (direct experience). For these scales, a character value could be used instead. Users of these variables are advised that multiplying ordinal scales to get an overall, summary estimate of exposure should be undertaken with caution. While the asbestos exposure ranking is generally indicative of a range of concentrations, no actual measurements were available to the authors for the workplaces of study subjects. Therefore, it is recommended that they be considered relative exposure values. For all other agents, the values given are relative to other exposures in the group (e.g., silica exposure in coal processing is less than in stone dressing). However there is no equivalency between groups of exposures; for example, a ''medium'' exposure to ionizing radiation and nickel would not be equivalent.

Based on our experience with the system, several changes might be considered to increase its usefulness. First, the detail for types of exposure settings could be expanded, if the information was 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 general purpose services. Secondly, the format could be expanded to include separate assessments to

a single agent if exposure occurs during routine work and also during a part-time job. For example, if an individual with the job title of auto mechanic did brake work and reportedly also repaired furnaces (perhaps as part of a second or part-time job), the two activities involve different fiber types and could represent different exposure frequency and intensity. Thirdly, the system should be designed to automatically copy up to 10% of records for evaluation of intra-rater variability.

CONCLUSIONS

The approach presented was used during the review of occupational histories derived from next-of-kin interviews to catalogue information on data quality, the data elements used in making the exposure assessment, the experience of the reviewer, and an evaluation of the knowledge level of the respondent. Both overall work record quality and the usefulness of the information to evaluate each specific exposure can be noted. When analyzed across the exposures of interest in this evaluation, differences in the quality of the data, the experience of the reviewer and the knowledge of the respondent were noted.

Use of this type of rating scheme in future studies where industrial hygienists are asked to review records to estimate exposure will provide documentation of the reasons for the assessment and allow evaluation of the impact of data quality on study results and exploration of case-response bias. Additional research is needed to evaluate the usefulness of these factors in other settings, and intra-rater and inter-rater variability. These results from further work can then be used to understand the generalizability of the approach to exposure assessment by reviewers of work histories.

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REFERENCES

Antman KH, Corson JM, Li FP, Greenberger J, Sytkowski A, Henson DE, Weinstein L. 1983. Malignant mesothelioma following radiation exposure. J Clin Oncol 11:695–700.

Axelsson G, Rylander R, Schmidt A. 1980. Mortality and incidence of tumors among ferrochromium workers. Br J Ind Med 37:121–127.

Bertazzi PA, Pesatori AC, Zocchetti C, Latocca R. 1989. Mortality study of cancer risk among oil refinery workers. Int Arch Occup Environ Health 61:261–270.

Bouchardy C, Schuler G, Minder C, Hotz P, Bousquet A, Levi F, Fisch T, Torhorst J, Raymond L. 2002. Cancer risk by occupation and socioeconomic group among men—a study by The Association of Swiss Cancer Registries. Scand J work Environ Health 28(Suppl 1):1–88.

Brenner J, Sordillo PP, Magill GB, Bolbey RB. 1982. Malignant mesothelioma of the pleura: Review of 123 patients. Cancer 49:2431–2435.

Chabot JF, Beard D, Langlois AJ, Beard JW. 1970. Mesotheliomas of peritoneum, epicardium, and pericardium induced by strain MC29 avian leukosis virus. Cancer Res 30:1298–1308.

Cicala C, Pompetti F, Carbone M. 1993. SV40 induces mesotheliomas in hamsters. Am J Path 142:573–574.

Coggon D, Inskip H, Winter P, Pannett B. 1995. Differences in occupational mortality from pleural cancer, peritoneal cancer, and asbestosis. Occup Environ Med 52:775–777.

Copeland KT, Checkoway H, McMichael AJ, Holbrook RH. 1977. Bias due to misclassification in estimation of relative risk. Am J Epidemiol 105:488–495.

Decoufle P. 1980. Mesothelioma among shoeworkers. Lancet 1:259.

deMarco R, Bernardinelli L, Mangione MP. 1988. Death risk due to tumors of the respiratory system in workers imployed in chromate production. Med Lav 79:368–376.

Engholm G, Englund A. 1982. Cancer incidence and mortality among Swedish painters. In: Englund K, Ringen A, Mehlman M, editors. Advances in modern environmental toxicology. Vol II. Princeton: Princeton Scientific. p 173–185.

Englund A. 1980. Cancer incidence among painters and some allied trades. J Toxicol Environ Health 6:1267–1273.

Finkelstein MM. 1996. Asbestos-associated cancers in the Ontario refinery and petrochemical sector. Am J Ind Med 30:610–615.

Frazee IA. 1955. Automotive collision work. Chicago: American Technical Society.

Gennaro V, Ceppi M, Boffetta P, Fontana V, Perrotta A. 1994. Pleural mesothelioma and asbestos exposure among Italian oil refinery workers. Scand J Work Environ Health 20:213–215.

Gennaro V, Finkelstein MM, Ceppi M, Fontana V, Montanaro F, Perrotta A, Puntoni R, Silvano S. 2002. Mesothelioma and lung tumors attributable to asbestos among petroleum workers. Am J Ind Med 37: 275–282.

Gerin M, Siemiatycki J, Keper H, Begin D. 1985. Obtaining occupational exposure histories in epidemiologic case-control studies. J Occup Med 27:420–426.

Giarelli L, Bianchi C, Grandi G. 1992. Malignant mesothelioma of the pleura in Trieste, Italy. Am J Ind Med 22:521–530.

Gilks B, Hegedus C, Freeman H, Fratkin L, Churg A. 1988. Malignant peritoneal mesothelioma after remote abdominal radiation. Cancer 61:2019–2021.

Gleason MN. 1957. Clinical toxicology of commercial products. Baltimore: Williams & Wilkins.

Gleason MN. 1963. Clinical toxicology of commercial products. Baltimore: Williams & Wilkins.

Gold B, Kathren RL. 1998. Causes of death in a cohort of 260 plutonium workers. Health Phys 75:236–240.

Grayson M, editor. 1987–1984. Kirk–Othmer Encyclopedia of Chemical Technology. 3rd edition. New York: John Wiley & Sons.

Hahn FF, Lundgren DL. 1992. Pulmonary neoplasms in rats that inhaled cerium-144 dioxide. Toxicol Pathol 20:169–178.

Hanis NM, Holmes TM, Shallengerger G, Jones KE. 1982. Epidemiologic study of refinery and chemical plant workers. J Occup Med 24: 203–212.

Hanis NM, Shallengerger LG, Donaleski DL, Sales EA. 1985a. A retrospective mortality study of workers in three major U.S. refineries and chemical plants. Part 1: Comparisons with U.S. population. J Occup Med 27:283–292.

Hanis NM, Shallenberger LG, Donaleski DL, Sales EA. 1985b. A retrospective mortality study of workers in three major U.S. refineries and chemical plants. Part II: Internal comparisons by geographic site, occupation, and smoking history. J Occup Med 27:361–369.

Heineman EF, Bernstein L, Stark A, Sprirtas R. 1996. Mesothelioma, asbestos, and reported history of cancer in first-degree relatives. Cancer 77:549–554.

Heuper WC. 1952. Experimental studies in metal carcinogenesis. Tex Pep Biol Med 10:167–186.

Hirsch A, Brochard P, DeCremous H, Erkan L, Sebastien P, Bignon J. 1982. Features of asbestos-exposed and unexposed mesothelioma. Am J Ind Med 3:413–422.

Huebner WW, Schnatter AR, Nicolich MJ, Jorgensen G. 1997. Mortality experience of a young petrochemical industry cohort—1979–1992 follow-up study of US-based employees. J Occup Environ Med 39:970–982.

Hueper W. 1959. Carcinogenic studies on water-soluble and insoluble macromolecules. AMA Arch Pathol 67:589–617.

Hueper W. 1960. Experimental production of cancer by means of implanted polyurethane plastic. Am J Clin Pathol 34:328–333.

Hueper WC. 1964. Cancer induction by polyurethane and polysilicone plastics. J Natl Cancer Inst 33:1005–1027.

Hueper W, Payne W. 1959. Experimental cancers in rats produced by chromium compounds and their significance to industry and public health. Am Ind Hyg J 20:273–280.

Ilgren EB, Wagner JC. 1991. Background incidence of mesothelioma: Animal and human evidence. Regul Toxicol Pharmacol 13:133–149.

Kirk RE, Othmer DF. 1980. Encyclopedia of chemical technology. 3rd edition. Vol 9. New York: John Wiley & Sons.

Kroschwitz JI, editor. 1991–1995. Kirk–Othmer Encyclopedia of Chemical Technology. 4th edition. New York: John Wiley & Sons.

Lee KP, Kelly DP, Kennedy GL, Jr. 1983. Pulmonary response to inhaled Kevlar aramid synthetic fibers in rats. Toxicol Appl Pharmacol 71:242–253.

Lentz TJ, Rice CH, Lockey JE, Succop PA, Lemasters GK. 1999. Potential significance of airborne fiber dimensions measured in the U.S. refractory ceramic fiber manufacturing industry. Am J Ind Med 36:286–298.

Lynge E, Rix BA, Villadsen E, Andersen I, Hink M, Olsen E, Moller UL, Silfverberg E. 1995. Cancer in printing workers in Denmark. Occup Environ Med 52:738–744.

Malker HR, Malker BK, Blot WJ. 1983. Mesothelioma among sugar refinery workers. Lancet 2:858.

Mast RW, McConnell EE, Anderson R, Chevalier J, Kotin P, Bernstein DM, Thevenaz P, Glass LR, Miiller WC, Hesterberg TW. 1995. Studies on the chronic toxicity (inhalation) of four types of refractory ceramic fiber in male Fischer 344 rats. Inhal Toxicol 7:425–467.

McClure H, Graham C. 1973. Malignant uterine mesothelioma in squirrel monkeys following diethylstilbesterol administration. Lab Anim Sci 23:493–497.

McDonald AD, Harper A, El Attar OA, McDonald JC. 1970. Epidemiology of primary malignant mesothelial tumors in Canada. Cancer 26:914–919.

Mehlman MA. 1991. Dangerous and cancer-causing properties of products and chemical in the oil refining and petrochemical industry: Part V—asbestos-caused cancers and exposure of workers in the oil refining industry. Toxicol Ind Health 7:53–71.

Miller BG, Searl A, Davis JMG, Donaldson K, Cullen RT, Bolton RE, Buchanan D, Soutar CA. 1999. Influence of fibre length, dissolution, and piopersistence on the production of mesothelioma in the rat peritoneal cavity. Ann Occup Hyg 43:155–166.

National Occupational Hazards Survey (NOHS). 1977. National Occupational Hazards Survey. Vol 3. Survey analysis and supplemental tables. Cincinnati, OH: National Institute for Occupational Safety and Health. Department of Health, Education, and Welfare. Publication number 78–114.

Nicholson WJ, Perkel G, Selikoff IJ. 1982. Occupational exposure to asbestos: Population at risk and projected mortality—1980–2030. Am J Ind Med 3:259–311.

NIOSH. 1989. NIOSH Method 7400, revision no. 3, NIOSH Manual of Analytical Methods. 3rd edition. Cincinnati OH: US Department of Health and Human Services, NIOSH.

NTP. 1986. Toxicology and carcinogenesis studies of dichloromethane. Report #306. NIH Publication 78–114.

Oels HC, Harrison EG, Carr DT, Bernatz PE. 1971. Diffuse malignant mesothelioma of the pleura: A review of 37 cases. Chest 60:564–570.

Payne W. 1960. Production of cancers in mice and rats by chromium compounds. J Natl Cancer Inst 21:50–54.

Pelnar PV. 1988. Further evidence of nonasbestos-related mesothelioma. A review of the literature. Scand J Work Environ Health 14:141–144.

Peterson JT, Greenberg SD, Buffler PA. 1984. Non-asbestos-related malignant mesothelioma: A review. Cancer 54:951–960.

Pott F, Ziem U, Reiffer F, Huth F, Ernst H, Mohr U. 1987. Carcinogenicity studies on fibres, metal compounds, and some other dusts in rats. Exp Pathol 32:129–152.

Rice C, Harris RL, Jr., Lumsden JC, Symons MJ. 1984. Reconstruction of silica exposures in North Carolina dusty trades. Am Ind Hyg Assoc J 45:689–696.

Roggli VL, McGavran MH, Subach J, Sybers HD, Greenberg SD. 1982. Pulmonary asbestos body counts and electron probe analysis of asbestos body cores in patients with mesothelioma: A study of 25 cases. Cancer 50:2423–2432.

Roller M, Pott F, Kamino K, Althoff GH, Bellmann B. 1996. Results of current intraperitoneal carcinogenicity studies with mineral and vitreous fibres. Exp Toxicol Pathol 48:3–12.

Rushton L. 1993. Further follow up of mortality in a United Kingdom oil distribution centre cohort. Br J Ind Med 50:561–569.

Sanders CL. 1992. Pleural mesothelioma in the rat following exposure to $^{239}PuO_2$. Health Phys 63:695–697.

Schmidt S. 1994. A Comparison of Three Methodologies Used for Identifying Possible Occupational Exposures to Specific Substance for Retrospective Occupational Epidemiologic Studies, Doctoral Dissertation. Cincinnati, OH: University of Cincinnati.

Siemiatycki J. 1991. Risk factors for cancer in the workplace. In: Boca Raton: CRC Press.

Sinks T, Goodman MT, Kolonel LN, Anderson B. 1994. A case-control study of mesothelioma and employment in the Hawaii sugarcane industry. Epidemiology 5:466–468.

Snellings W, Weil C, Marmput R. 1984. A two-year inhalation study of the carcinogenic potential of ethylene oxide in Fishcher F344 rats. Toxicol Appl Pharmacol 75:105–117.

Spirtas R, Keehn RJ, Beebe GW, Wagner JC, Hochholzer L, Davies JNP, Ortega LG, Sherwin RP. 1986. Results of a pathology review of recent US mesothelioma cases. Accompl Oncol 1:144–152.

Spirtas R, Heineman EF, Bernstein L, Beebe GW, Keehn RJ, Stark A, Henderson BE, Harlow BL, Benichou J. 1994. Malignant mesothelioma: Attributable risk of asbestos exposure. Occup Environ Med 51:804–811.

Stanton MF, Wrench C. 1972. Mechanisms of mesothelioma induction with asbestos and fibrous glass. J Natl Cancer Inst 48:797–821.

Stanton MF, Layard M, Tergeris A, Miller E, May M, Kent E. 1977. Carcinogenicity of fibrous glass pleural response in the rat in relation to fiber dimension. J Natl Cancer Inst 58:587–603.

Stewart PA, Stewart WF. 1994. Occupational case-control studies: II. Recommendations for exposure assessment. Am J Ind Med 26:313–326.

Stewart PA, Herrick RF, Feigley CE, Utterback DF, Hornung R, Mahar H, Hayes R, Douthit DE, Blair A. 1992. Study design for assessing exposures of embalmers in a case-control study. Part 1. Monitoring results. Appl Occup Environ Hyg 7:532–540.

Teta MJ, Lewinsohn HC, Meigs JW, Vidone RA, Mowad LZ, Flannery JT. 1983. Mesothelioma in Connecticut, 1955–1977; occupational and geographic associations. J Occup Med 25:749–756.

Thomas Register of American Manufacturers and Thomas Register Catalog File. 1940, 1960, 1965, 1970. New York: Thomas Publishing Company.

Vaughan GL, Trently SA. 1996. The toxicity of silicon carbide whiskers, a review. J Environ Sci Health A31:2033–2054.

Warren S, Brown CE, Chute RN, Federman M. 1981. Mesothelioma relative to asbestos, radiation, and methylcholanthrene. Arch Pathol Lab Med 105:305–312.