

## **Development, Use, and Availability of a Job Exposure Matrix Based on National Occupational Hazard Survey Data**

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A job exposure matrix has been developed based on potential exposure data collected during the 1972-1974 National Occupational Hazard Survey (NOHS). The survey sample was representative of all U.S. non-agricultural businesses covered under the Occupational Safety and Health Act of 1970 and employing eight or more employees. Potential worker exposure to all chemical, physical, or biological agents was recorded during the field survey if certain minimum guidelines for exposure were met. The job exposure matrix (JEM) itself is a computerized database that assists the user in determining potential chemical or physical exposures in occupational settings. We describe the structure and possible uses of the job exposure matrix. In one example, potential occupational exposures to elemental lead were grouped by industry and occupation. In a second example, the matrix was used to determine exposure classifications in a hypothetical case-control study. Present availability as well as future enhancements of the job exposure matrix are described.

**Key words:** occupational exposures, surveillance, industry, occupation, National Occupational Hazard Survey, lead, case-control study

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### **INTRODUCTION**

In studying occupational health, a knowledge of occupation-specific exposures is useful since exposures to many potentially hazardous substances may occur in the workplace at high concentrations. Because exposures vary for occupations and industries, several approaches have been used to identify occupation-specific exposure information. Direct quantitative exposure measurements, if they are available, are useful to determine exposure categories for analytic field studies. However, many studies of mortality or morbidity are conducted by using vital statistics or other record systems where the only exposure data recorded are the decedent's or respondent's occupation or industry. For analysis of these studies, a classification system linking industry, occupation, and exposure would be useful. A job exposure matrix (JEM) is such a classification system linking occupational titles with occupational exposures.

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JEMs have been used to identify industries or occupations in which exposure to given chemical or physical agents might occur.

Different approaches have been used to develop JEMs, depending on the sources of exposure data and intended usage of the JEM. JEMs have been constructed by using job titles, employee interviews, and company records for individual plants or industries [Gamble et al., 1976; Kaupinnen et al., 1986; Kaupinnen and Partanen, 1988]. Such matrices may be extensive and include quantitative exposure measurements. They are specific to industries for which they were constructed. More general JEMs covering a range of industries have also been developed in which exposure agents and indices of exposure in individual occupations were determined from the literature or by a panel composed of chemists and industrial hygienists [Hoar et al., 1980; Olsen et al., 1986; Pannett et al., 1985; Vineis and Magnani, 1985]. Substances included in these JEMs are limited to those described in the literature or known to the panel. Another approach, the assignment of individual exposures by a team of chemists and industrial hygienists following an in-depth interview of subjects, has been followed in a large case-control study in Montreal, Canada [Siemiatycki, 1984, 1988; Gerin, 1988].

A JEM has been developed by researchers at the National Institute for Occupational Safety and Health (NIOSH). This JEM, hereafter referred to as the JEM or NOHS-based JEM, is based on potential occupational exposure data recorded during the National Occupational Hazard Survey (NOHS), a national survey of businesses representative of U.S. industry. In this article, the development, structure, content, and possible uses of the NOHS-based JEM are described. Examples are included of a few uses of the JEM. Availability of the JEM and future enhancements are also described.

## **MATERIALS AND METHODS**

### **The National Occupational Hazard Survey**

The 1972–1974 National Occupational Hazard Survey (NOHS) [NIOSH, 1974, 1977, 1978] was a 2 year field survey conducted by NIOSH. It was intended to describe the health and safety conditions in the American workplace and to determine the extent of workers' exposure to chemical, physical, and biological agents. Data on potential exposures to all hazardous agents observed in the workplace were collected during the NOHS site visits for a sample of industries. The survey sample was representative of all non-agricultural businesses that were covered under the Occupational Safety and Health Act of 1970 and employed eight or more employees. Businesses with less than eight employees were considered to be too numerous and transient to survey accurately.

The NOHS sample consisted of 4,636 facilities in 67 metropolitan areas of the United States. The selection scheme was a two-stage process involving stratification and systematic selection procedures [NIOSH, 1974, 1977, 1978; Sieber, 1985]. The number of employees, Standard Industrial Classification (SIC), and geographical location of each facility were important characteristics in the selection process. The number of facilities surveyed and average number of employees per facility are shown by size category, i.e., number of employees, in Table I.

**TABLE I. Number of Facilities Surveyed and Average Number of Employees by Facility Size and Industrial Category (1972–1974 NOHS)**

Industrial category	SIC range	Total no. of facilities surveyed	Facility size (no. of employees)	Percent of facilities observed in size category	Average no. of employees in size category
Agriculture, forestry, fishing	07–09	47	8–99	94	22
			100–249	6	212
			250 +	0	0
Oil & gas extraction	13	32	8–99	63	36
			100–249	28	200
			250 +	9	667
Construction	15–17	503	8–99	82	30
			100–249	17	173
			250 +	1	665
Manufacturing	19–39	2,751	8–99	57	39
			100–249	34	223
			250 +	8	1,735
Transportation, communication, electric, gas, and sanitary services	40–49	308	8–99	62	36
			100–249	29	218
			250 +	9	2,356
Wholesale, retail trade	50–59	506	8–99	83	27
			100–249	15	194
			250 +	2	1,482
Finance, insurance, real estate	60–67	144	8–99	77	29
			100–249	21	198
			250 +	2	1,797
Services	70–89	345	8–99	76	30
			100–249	17	187
			250 +	7	954
Total		4,636	8–99	66	34
			100–249	28	215
			250 +	6	1,694

### Data Collection

Data for the NOHS were collected by 20 surveyors, all recent engineering graduates specifically trained for the NOHS. Training of the surveyors included completion of a 9 week course in industrial hygiene, 3 weeks of field training in survey and investigation techniques with state industrial hygienists, and completion of a trial field inspection using the official NOHS field manuals and recording forms.

Potential exposure information was collected during a walk-through inspection of each facility. Potential exposure to any agent was recorded if the following guidelines were met:

1. a chemical, physical, or tradenamed product must have been observed in sufficient proximity to an employee that one or more physical phases of the agent were

likely, in the judgment of the surveyor, to enter or contact the body of the employee; and

2. the potential exposure must have met minimum duration guidelines, i.e., it must have presented a potential exposure for at least 30 minutes per week (on an annual average) or at least once per week for 90% of the weeks of the work year.

Data on the presence of engineering controls over potential exposure and duration of potential exposure in each facility were recorded. Duration of potential exposure was defined as full-time (if potential exposure time was greater than 4 hours per day on a daily basis of at least 90% of the company's work year) or part-time.

Potential exposures recorded during the survey were classified into two categories: tradename or actual exposures. If the surveyors were able to observe and identify a specific exposure agent during the survey, it was called an "actual exposure." In cases where an exposure agent occurred as a formulated product labeled with a brand name, the ingredients were later identified; these were called "tradename exposures." Roughly 70% of the data collected in the NOHS was associated with tradename products and component ingredients were determined for 85% of these tradename products.

Data on 8,342 different potential exposure agents observed in facilities representing 639 SIC codes and 442 occupations were included in the NOHS. Facility activity was coded by four-digit 1967 SIC code [OMB, 1972], occupation by 1970 Bureau of the Census occupation codes [Bureau of The Census, 1970], and agent by a unique five-digit hazard code assigned at NIOSH. Unique hazard codes were developed by NIOSH because many agents were observed during the NOHS that had not been assigned codes by other conventions such as a Chemical Abstracts (CAS) number or a Registry of Toxic Effects of Chemical Substances (RTECS) number. Cross-referencing of hazard codes to Chemical Abstracts and Registry of Toxic Effects of Chemical Substances numbers has been completed. All data were coded into machine-readable format and stored on magnetic tape for use with an IBM 3090 model 400 computer system.

National estimates of the number of employees in each industry surveyed in the NOHS were calculated by using payroll information and ratio estimation techniques [NIOSH, 1974, 1977, 1978; Sieber, 1985].

### **Development and Structure of the NOHS-Based Job Exposure Matrix**

The NOHS-based job exposure matrix is a three-level classification system in which potential worker exposure information collected during the National Occupational Hazard Survey (NOHS) walk-through inspection is classified by industry and occupation [Sieber, 1990]. Each level of classification is nested within the previous one. The three levels of classification in the JEM are thus industry, occupation within industry, and potential exposure within occupation within industry. The nested structure is important for flexibility in the use of the JEM since the maximum data may be included at each level of classification, and data may be easily obtained at each level of classification.

In order to arrange potential exposure data from the NOHS in a form that could be easily retrieved from the JEM, certain simplifications of the data were made for presentation in the JEM. The physical form of the agent, type of engineering control, and whether or not the control measure was functioning were not indicated in the JEM. Including this data would have greatly increased the size and computer storage

TABLE II. Data Included at Each Classification Level in the NOHS-Based JEM Level

Industry	Industry and occupation	Potential exposure
Industry code <sup>a</sup>	Industry code <sup>a</sup> Occupation code <sup>b</sup>	Industry code <sup>a</sup> Occupation code <sup>b</sup> Hazard code CAS number <sup>c</sup> RTECS number <sup>c</sup>
No. of facilities surveyed within SIC	No. of facilities surveyed where this SIC-occupation group was observed	No. of facilities in SIC-occupation group where agent was observed
No. of employees observed within SIC	No. of employees observed in SIC-occupation group	No. of employees observed to be potentially exposed to agent in SIC-occupation group
Estimate of total no. of employees in SIC	Estimate of total no. of employees in SIC-occupation group	Estimate of total no. of employees potentially exposed to agent in SIC-occupation group No. of employees potentially exposed full time to agent in SIC-occupation group No. of employees with actual exposure to agent in SIC-occupation group No. of employees in SIC-occupation group working in facilities with no form of control over potential agent exposure

<sup>a</sup>Available using either SIC or Bureau of the Census codes.<sup>b</sup>Bureau of the Census occupation codes.<sup>c</sup>If available.

requirements for the JEM. Such information is available on request from the authors, however. Potential exposures to substances whose individual product formulations could not be resolved were also excluded from the JEM in order to present only data based on known product formulations.

The organization of occupational information from the NOHS walk-throughs into the job exposure matrix format followed a series of steps. First, potential data to be included in the JEM were selected. Next, three computer files, each including data specific to one classification level in the JEM, were created. One file included data for the industry as a whole, one for each occupation observed in the industry, and one for each potential exposure agent observed in each occupation in the industry. The three files were merged to form the JEM. All information at each step in the processing sequence was categorized by the size of the facility in which the observations were made (small, 8–99 employees; medium, 100–499 employees; large, over 500 employees).

Data included at each classification level in the JEM are shown in Table II. Data at each level of classification are unique to that level. Data on industrial employment, for example, are found at the industry level, on employment in an industry/occupation

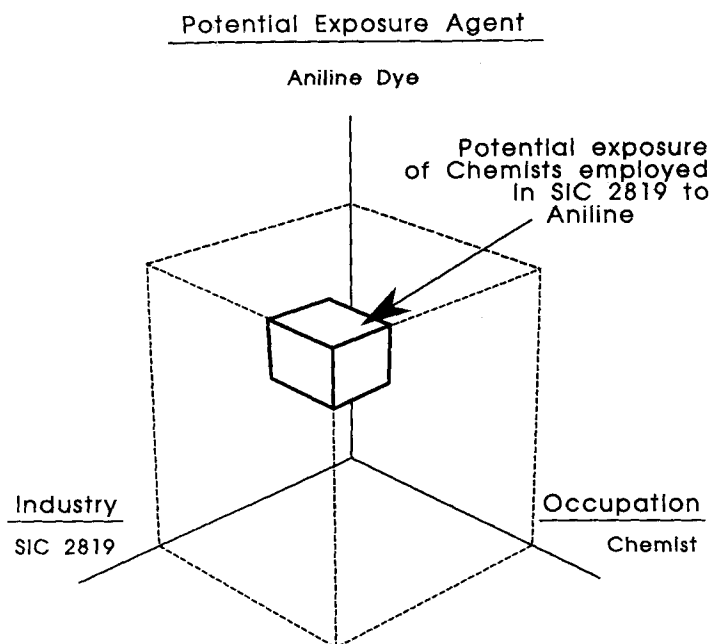


Fig. 1. Representation of the JEM for data retrieval.

grouping are at the industry/occupation level, and on number of employees potentially exposed to the agent in the industry/occupation group are at the potential exposure level. Percentages of employees potentially exposed to an agent in an industry or industry/occupation group may be found by using this scheme.

The JEM may be thought of as a three-dimensional array with axes for each level of classification as shown in Figure 1. In Figure 1, information on all agents to which chemists employed in SIC 2819 (Manufacture of Industrial Inorganic Chemicals, N.E.C.) were observed to be potentially exposed may be obtained at the intersection of the industry and occupation axes. Information on potential exposure of chemists employed in SIC 2819 to aniline may be obtained from the cell at the intersection of the industry, occupation, and potential exposure axes. Occupations or industries in which employees may be potentially exposed to aniline dye may be found from the intersections of the occupation or industry axes, respectively, with the potential exposure axis.

## USE OF THE NOHS-BASED JEM

The JEM may be used to associate potential exposure with specific occupational settings as illustrated in the following two examples. The first example illustrates the use of the NOHS-based JEM to list the occupational settings where potential worker exposure to elemental lead was recorded. The second example illustrates the use of the NOHS-based JEM with vital statistics data to objectively determine exposure classifications by using usual occupation and industry of employment.

**TABLE III. Industry/Occupation Groups Where 50 or More Employees Were Observed to Have Potential Exposure to Metallic Lead (NOHS-Based JEM)**

Industry	Occupation	No. of employees observed in industry/occupation group	Percent of employees potentially exposed to metallic lead
Water transportation	Industrial machinery repairers	141	56.7
Radio, TV, and communication equipment	Tool and die makers	215	46.5
Miscellaneous nonmetallic mineral and stone products	Industrial machinery repairers	161	34.2
Ship- and boat-building and repairing	Machinist	671	30.8
Telephone communications	Telephone line installers and repairmen	835	28.6
Ship- and boat-building and repairing	Plumbers, pipefitters, and steamfitters	428	25.7
Blast furnaces, steelwork, rolling and finishing mills	Construction laborers	276	19.2
Machinery, except electrical, N.E.C.	Laborers, except construction	369	15.7
Newspaper publishing and printing	Typesetters and compositors	618	14.6
Blast furnaces, steelworks, rolling finishing mills	Plumbers, pipefitters, and steamfitters	560	9.5
Machinery, except electrical, N.E.C.	Assemblers	2,056	5.4
Construction	Plumbers, pipefitters, and steamfitters	1,520	3.3
Radio, TV, and communication equipment	Electrical and electronic equipment assemblers	3,739	1.6

### Profiling Potential Exposures to a Single Agent: Elemental Lead

The use of 59 different lead compounds in 98 different industries was listed in the JEM. For this example, only the use of elemental lead was considered.

Potential exposure to elemental lead was observed in 66 occupations across 59 industries. A total of 3,280 employees were observed to be potentially exposed to elemental lead. Those industry/occupation groups where 50 or more employees were observed in the NOHS to be potentially exposed to metallic lead are shown in Table III. The number observed and percent of employees potentially exposed in the respective industry-occupation groups are also shown in Table III; 57% of industrial machinery repairers observed in the water transportation industry were observed to be potentially exposed to elemental lead, while just 1.6% of electrical equipment assemblers observed in the radio, TV, and communication equipment industry were potentially exposed to elemental lead.

**TABLE IV. Age-Adjusted Odds Ratios for Leukemia Deaths With Potential Exposure to Ionizing Radiation Determined by the NOHS-Based JEM**

Exposure category	Age at death	Cases		Controls		Odds ratio	95% confidence interval
		Exposed	Total	Exposed	Total		
By industry	all	56	368	716	4,317	.9	(.7, 1.2)
	<65	27	155	324	1,555	.8	(.5, 1.2)
	64 +	29	213	392	2,762	1.0	(.6, 1.4)
By occupation	all	13	368	115	4,317	1.3	(.7, 2.3)
Within industry	<65	9	155	56	1,555	1.7	(.8, 3.4)
	64 +	4	213	59	2,762	.9	(.3, 2.4)

### Determining Exposure Classifications for Epidemiologic Studies

Potential exposure data obtained from the NOHS-based JEM may be used as an objective measure of exposure in epidemiological studies [Preston-Martin et al., 1989; Brackbill et al., 1990]. Exposure to ionizing radiation has been associated with the development of leukemia [Court Brown and Doll, 1965; Matanoski et al., 1975; Rutstein et al., 1983]. The use of the NOHS-based JEM to determine exposure classifications objectively will be illustrated in a hypothetical case-control study of the association of potential exposure to ionizing radiation and leukemia or aplastic anemia.

Cases and controls were selected from 1968–1978 Rhode Island death certificates [Kelley and Gute, 1986]. All deaths from leukemia were defined as cases for the analysis. A 10% random sample of all non-case deaths was drawn for the controls.

Industries and occupations where potential exposure to ionizing radiation was observed were objectively identified by using the JEM. All cases and controls whose death certificates listed an industry and/or occupation with potential for exposure to ionizing radiation according to the JEM were considered to be exposed. All other occupational groups were considered to have no exposure. Age-adjusted odds ratios were calculated by using the Mantel-Haenszel method [Schlesselman, 1982; Rothman and Boice, 1979]. Fisher's exact test was used for probability testing when expected cell sizes were smaller than five. The analysis was performed first by using potential exposure in industry as the grouping variable, and then repeated by using exposure within the industry-occupation pair as the grouping variable.

Results for this analysis are shown in Table IV. Therein, odds ratios appear to be greater when classification is by potential exposure in an industry-occupation group, rather than by potential exposure in the industry alone. The analysis is intended as an example of exposure groupings possible by using the NOHS-based JEM.

### ADVANTAGES AND LIMITATIONS OF THE NOHS-BASED JEM

The examples presented are intended to illustrate the use of the NOHS-based JEM in the identification of potential exposures associated with specific industries and/or occupations. Potential exposure information in the JEM was collected primarily from a sample of manufacturing facilities employing 8–99 employees (see Table I). The use of the JEM in studies of industries that are similar to those included in the JEM sample should offer several advantages in analysis. One advantage might be a reduction in cost. Rather than obtaining estimates of exposure by methods such as



interviews or from a panel, such information could be obtained through application of the JEM. Other variables included in the JEM which might be used as surrogate exposure data are full- or part-time exposure to the agent and the estimated proportion of employees observed to be potentially exposed to the agent.

One use of a JEM in epidemiologic studies has been to classify employees by hazardous exposure in order to study the association between occupational disease and exposure [Coggon et al., 1984; Gamble et al., 1976; Hoar et al., 1980; Hinds et al., 1985; Linet et al., 1987; Sieber et al., 1986; Spitz and Johnson, 1985; Siemiatycki et al., 1987; Wilkins and Sinks, 1984]. The potential for misclassification of exposure in JEMs has caused some researchers to question their value. Such misclassifications would tend to bias any association toward the null value [Kaupinnen and Partanen, 1988]. An approach to minimizing misclassification error in the NOHS-based JEM might be to determine the percent of employees in an occupational group potentially exposed to an agent being studied, as shown in Table III. Those occupational groups with the highest percentages of employees potentially exposed to the agent might be studied further. The potential for misclassification using this and other JEMs should be explored further.

In using the NOHS-based JEM, it should be remembered that all data included in it are based on field observation and are representative only of those occupational groups and industries observed. Other sources of exposure information, such as the literature or panels of chemists of industrial hygienists, were not used. Field observations were made by teams of surveyors who received a standardized training in industrial hygiene and field techniques, and who followed a standard procedure while collecting and recording data in the field [NIOSH, 1974, 1977, 1978].

Although the JEM may provide additional potential exposure information for health studies, study results are still dependent on the quality of data collected in the study. A common limitation is the lack of a complete work history for which potential exposures in each occupation the worker has had may be determined. Another limitation is confounding of occupations or job titles. Job title or occupation may vary from one industry to another or even vary in the same industry over time. Job titles are especially important in the NOHS-based JEM because of the specific occupation and industry classifications in the JEM. For proper use of the JEM, all occupations should be coded consistently.

Potential exposure data from the JEM may be linked with data from other data sets including physical or carcinogenic properties of the exposure agent. This linkage is possible because the format of the JEM allows cross-referencing of Chemical Abstracts (CAS) codes, Registry of Toxic Effects of Chemical Substances (RTECS) codes, and NIOSH hazard codes.

## AVAILABILITY OF THE NOHS-BASED JEM

The NOHS-based JEM file fits on a single reel of magnetic tape for use with a mainframe computer. Extensive documentation on the development and use of the JEM, sample programs to generate results presented in this article, and files including labels corresponding to the numeric codes used throughout the JEM are available from the author. All data retrieval and reporting software is written by using the Statistical Analysis System [SAS, 1979]. Data from the NOHS-based JEM may be downloaded from the mainframe to a microcomputer, and a microcomputer version

TABLE V. No. of Records in Versions of the NOHS-Based JEM File

Version	Classification system		Total no. of records
	Industry	Occupation	
.1	1967 SIC	1970 census	535,771
1.0	1970 census	1970 census	438,073
2.0	1980 census	1980 census	418,867

of the JEM is being developed. Comments from JEM users are welcomed by the authors.

The 1967 SIC industry and 1970 Bureau of the Census occupation codes used in the initial version of the JEM have been converted to other coding systems. Versions of the JEM using 1970 and 1980 Bureau of the Census industry and occupation codes are available. In an edit of industry and occupation codes, 99% of the 16,000 industry and occupation groupings were translated directly from the 1967 SIC to 1970 census industry codes. The number of computer records in each version of the NOHS-based JEM are shown in Table V.

A version of the JEM using the 1972 SIC industry codes is planned for compatibility of the NOHS-based JEM with a similar JEM to be developed by using data from the 1981–1983 National Occupational Exposure Survey (NOES) [NIOSH 1988, 1990a,b]. The NOES is identical to the NOHS but conducted 10 years later.

## CONCLUSION

The NOHS-based JEM is based on data from a national U.S. field study. It includes potential exposure data recorded on over 8,000 agents observed in a sample of workplaces covered under the Occupational Safety and Health Act and which employed eight or more workers.

Possible applications of the NOHS-based JEM include the analyses of occupational and environmental health research data. It may be of particular use in registry or other record-based epidemiologic studies where occupational exposure is not limited to a specific facility and where exposure to a specific agent is not easily determined.

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