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Exposure to Potential Occupational Asthmogens: Prevalence Data from the National Occupational Exposure Survey

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Few data are available about the prevalence of occupational exposures to agents which can cause occupational asthma or aggravate preexisting asthma (asthmogens). Using potential occupational exposure data from the National Occupational Exposure Survey (NOES) of 1980–1983, we investigated the number of asthmogen exposures, asthmogen-exposure(s) per production worker, and unprotected occupational asthmogen exposures in different industries and occupations. Data for the entire United States were used to generate estimates of occupational exposure at two selected state and local levels. It was estimated that 7,864,000 workers in the surveyed industries were potentially exposed to one or more occupational asthmogen(s) in the United States. The average number of observed potential exposures per asthmogen-exposed worker was 4.4, and varied from 11.9, in the Water Transportation industry, to 1.2 in Local and Suburban transportation. The largest number of observed potential exposures was recorded in the Apparel and Other Finished Products (garment) industry. This work and further analyses using this approach are expected to contribute to a better understanding of the epidemiology of occupational asthma, and to serve as a guide to target future occupational asthma surveillance efforts. Am. J. Ind. Med. 31:195–201, 1997.
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INTRODUCTION

More than 200 agents have been characterized as potential causes of occupational asthma (asthmogens), and the list continues to grow with the introduction of new chemicals in the workplace [Chan-Yeung, Lam, 1986; Chan-Yeung, Malo, 1995]. Although occupational asthma is a well-recognized clinical entity, it is difficult to diagnose and is probably grossly underreported. Consequently, there are no reliable estimates of its incidence and prevalence [Meredith et al., 1991; Chan-Yeung, Malo, 1995]. Furthermore, since careful documentation of exposure is one of the fundamental elements to the diagnosis of occupational asthma, the scarcity of information about exposures occurring in specific geographic areas has contributed to limiting the detection and prevention of occupational asthma.

We premised that estimates of prevalence of potential exposure to occupational asthmogens could be generated from hazard surveillance data available from the National Institute for Occupational Safety and Health (NIOSH). Beginning in 1980, NIOSH conducted a national survey intended to profile occupational exposure to chemical, physical, and biological agents. This survey, known as the National Occupational Exposure Survey (NOES), had been preceded in 1972–1974 by the National Occupational Hazard Surveillance (NOHS). The NOES consisted of management

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interviews and walk-through inspections of a sample of 4,490 industrial facilities in the United States. The database constructed from this survey permitted the estimation of the number of workers in the nation potentially exposed to specific agents, including asthmogens.

Regrettably, the NOES database has been underutilized by physicians and researchers interested in occupational asthma because the capabilities of the data system were inadequately understood [Greife et al., 1995]. Tabular estimates of the number of workers potentially exposed to individual asthmogens have been recently generated [Bernstein et al., 1993]. However, those summary tables did not account for overlap of asthmogen exposures (e.g., exposure of one individual worker to one or more asthmogens), nor did they identify those occupations and industries in which workers may be at higher risk of exposure to asthmogens and, consequently, occupational asthma.

Our goal in this study was to generate estimates of the number of workers potentially exposed to one or more asthmogens within different occupational and industrial classifications. We then modified these national estimates to permit the estimation of exposure prevalences in specific geographic locales.

METHODS

NOES

Detailed documentation about the NOES survey and data analyses methods have been published by and are available from NIOSH [U.S. Department of Health and Human Services–NIOSH, 1988; U.S. Department of Health and Human Services–NIOSH, 1989a; U.S. Department of Health and Human Services–NIOSH, 1989b]; a review was recently published [Greife et al., 1995]. Briefly, the survey was conducted between November, 1980 and May, 1983, and involved on-site visits by trained surveyors to a stratified probability sample of 4,490 industrial facilities with a minimum of eight employees each, which employed close to 1,800,000 persons. During the survey, each worker's occupation was classified using 3-digit 1980 Census codes [Bureau of the Census, 1980]. Each industrial facility was classified within a broad industrial category ('major group') by means of the 2-digit 1972 Standard Industrial Classification (SIC) codes [Office of Management and Budget–Technical Committee on Industrial Classification, 1972].

The sample of surveyed facilities was designed to be representative of virtually all non-agricultural, non-mining, and non-governmental businesses covered under the Occupational Safety and Health Act of 1970. Based on earlier NIOSH survey work, however, target industrial groups were selected. Accordingly, relatively little survey activity was performed in Wholesale or Retail Trade, and no facilities were surveyed in the Finance or Real Estate sectors. In all, 43 of the 85 2-digit 1972 SIC code businesses were defined as part of the target industrial groups to be surveyed. These were: SICs 7, 13, 15–17, 20–42, 44–51, 55, 72, 73, 75, 76, 80, and 84. It was estimated that these industries employed a total of 33.4 million workers in the United States at the time of the NOES.

A two-stage sampling strategy was used to select the actual sample from the national universe of eligible facilities. The first stage involved a random selection from strata defined by geography, number of employees, and concentration of establishments included in the target population. This resulted in the selection of 98 geographical areas in the United States (Primary Sampling Units). The second stage involved systematic sampling from a list of establishments ordered by number of employees and SIC codes. The effective refusal rate among establishments initially selected for inclusion in the NOES was 0.3%.

The NOES surveyors administered a standardized questionnaire to plant management, directly observed processes and operations, and recorded potential exposures for all employees based on direct observation in the surveyed workplaces. Note that the term 'potential exposure' is used in relation to all NOES observations of worker occupational exposure, because no environmental levels or industrial hygiene measurements were made (except for noise levels) due to the complexity and cost of attempting to do so on such a large scale. Direct observation involved recording the use of (and potential occupational exposure to) different agents, including tradenamed compounds. The latter required resolution of the individual components in a separate Tradename Ingredient Clarification operation. More than 12,000 different potential exposure agents and over 100,000 unique tradename products were seen during the walk-through visits. Survey observations also included the availability and use of exposure controls (respiratory protective equipment, ventilation, etc.), job title, worker gender, and process description. The stratification of the survey data by both SIC industry codes [Office of Management and Budget–Technical Committee on Industrial Classification, 1972] and census occupation codes [Bureau of the Census, 1980] allowed standardized retrieval.

Occupational Asthmogens

A study list of 367 potential occupational asthmogens in the NOES had been previously derived from literature search [Bernstein et al., 1993], and is available from the authors. This list includes agents that can be generally classified as: (a) allergens, i.e., agents capable of causing bronchoconstriction by an allergic or IgE-mediated mechanism; (b) irritants, which have been postulated to cause inflammatory bronchoconstriction, and may cause de novo asthma or aggravation of preexisting disease; or (c) pharmacologic bronchoconstrictors. Many agents, however, cannot

be conclusively classified at present because their pathogenic mechanism is unknown (e.g., isocyanates) [Chan-Yeung, Malo, 1995]. Furthermore, although definitive data are not available for all such agents, it is clear that they differ in their potential to cause or aggravate asthma in exposed workers.

Employment Figures

These refer exclusively to the target industrial groups covered by the NOES and described previously. For the purposes of this work, the following types of workforces were defined.

1. Total Workforce or Employment: All employees on the payroll within each 2-digit SIC industry covered by the NOES. The Total Workforce includes clerical or administrative personnel with very limited or no exposure to the agents investigated in the survey.
2. Production Workforce: Workers in each 2-digit SIC industry (out of the Total Workforce) that were observed to be potentially exposed to one or more of any of the agents (asthmogens or others) observed in the NOES. The proportion of workers in the Production Workforce (out of the Total Workforce) was 58.6% at the national level for all surveyed industries, and varied among different industries. By NOES estimate, this proportion ranged from 36% in Communications Services (SIC 48) to 80% in Apparel and Other Finished Products (SIC 23). Complete data are available from the authors.
3. Asthmogen-Exposed Workforce: The estimated number of production workers who were potentially exposed to one or more of the 367 occupational asthmogens previously mentioned within each 2-digit SIC and census occupation code. This is a subset of the Production Workforce defined in the previous paragraph.

This work was concerned almost exclusively with the last two workforces. Two-digit SIC code categories are used because the estimates produced are the most stable, in view of the sample sizes. All computer-generated NOES estimates were rounded to the nearest thousand for citation at the national and local level.

Asthmogen Exposure(s)

Workers could be potentially exposed to one or more of the 367 asthmogens on the study list at the time of the survey. From the existing NOES database, the total number of observed potential occupational exposures to one or more of these asthmogens by SIC code and census occupation code was initially obtained. This was accomplished by a computer algorithm which extracted those records, already cross-referenced to the list of agents. A previous algorithm had derived data on production workforce (as defined before) by 2-digit SIC code.

We were then able to obtain average number of potential asthmogen exposures per exposed production worker by both 2-digit SIC and 3-digit census occupation codes. The goal was to obtain a gross, indirect measure of risk of exposure (not of disease), and this process is similar to previous ones [Frazier et al., 1984; Pedersen et al.,(1983]. Furthermore, estimates at the national level were calculated for unprotected potential asthmogen exposures (observed occupational exposures with no exposure controls) per production worker by 2-digit SIC and by census occupation code. The estimates for SIC 23 (Apparel and Other Finished Products) are presented in this article for illustrative purposes. All estimates of potential asthmogen exposure per worker were calculated to two decimal places.

State and Local Data Estimates

Given NOES national estimates of the number of production and asthmogen-exposed workers, as well as total observed asthmogen exposures, extrapolation to state and local data was possible. For illustrative purposes, two geographic areas of particular interest to the first author were selected. These were Connecticut and the New York City metropolitan area (including the five boroughs of New York and the surrounding counties of Westchester, Putnam, and Rockland). The 1993 annual average employment statistics by 2-digit SIC classification for New York City were obtained from the Bureau of Labor Statistics in New York City. Connecticut annual average employment statistics for 1991 were obtained from the Connecticut Labor Department.

As discussed, we had calculated national estimates of the proportion of production workers in the total workforce, as well as the proportion of production workers potentially exposed to asthmogens by 2-digit SIC. Local estimates were then produced by applying national proportions to the local employment totals by 2-digit SIC. Local estimates of potential asthmogen exposures by each 2-digit SIC industry for the two localities in this study were calculated by applying the average number of potential asthmogen exposures per production worker at the national level to the estimated local production workforce. A summary table that allows similar extrapolations is available from the first author.

RESULTS

Results are presented in Table I for each geographic level (i.e., national, Connecticut, and New York City metropolitan area). Ranks one through ten are provided in parentheses for each variable and geographic level. In all, 22 industries are listed in the table where prevalence of

TABLE I. Industries with the Largest Estimated Number of Potential Asthmogen Exposures (EXPS), Potentially Asthmogen-Exposed Production Workforces (EXP-PWF) in the United States, Connecticut, and the New York City Metropolitan Area*

		National data			Connecticut data		New York metro data	
SIC	Industrial sector	EXPS (×1000)	EXP-PWF (×1000)	EXP/W	EXP-PWF (×1000)	EXPS (×1000)	EXP-PWF (×1000)	EXPS (×1000)
23	Apparel and other finished products	4802 (1)	463 (4)	10.37 (2)	2	19	32 (3)	329 (1)
37	Transportation equipment	2387 (2)	353 (6)	6.76 (7)	15 (3)	98 (1)	1	7
34	Fabricated metal products	2282 (3)	398 (5)	5.74	9 (6)	52 (3)	3	20 (10)
35	Machinery, except electronics	2222 (4)	549 (3)	4.05	9 (5)	37 (6)	3	13
17	Special trade contractors	2143 (5)	604 (2)	3.55	13 (4)	45 (5)	28 (5)	99 (4)
80	Health services	2051 (6)	856 (1)	2.40	32 (1)	78 (2)	79 (1)	190 (3)
33	Primary metal industries	1924 (7)	228	8.41 (5)	2	18	1	8
20	Food and kindred products	1902 (8)	292 (10)	6.51 (8)	2	13	4 (10)	29 (9)
30	Rubber and miscellaneous products	1290 (9)	218	5.91 (9)	3	19	3	17
28	Chemicals and allied products	1259 (10)	215	5.85 (10)	5	30 (7)	6 (9)	38 (8)
36	Electric and electronic equipment	1009	346 (7)	2.92	6 (10)	16	3	9
15	General building construction	990	344 (8)	2.87	4	13	8 (8)	22
24	Lumber and wood products	701	293 (9)	2.40	<1	<1	<1	<1
44	Water transportation	268	23	11.94 (1)	<1	<1	<1	<1
45	Transportation by air	870	86	10.0 (3)	1	8	na	na
76	Miscellaneous repair services	365	42	8.66 (4)	1	8	na	na
51	Wholesale trade–nondurable goods	119	17	6.84 (6)	3	18	3	23
73	Business services	774	258	3.00	16 (2)	48 (4)	57 (2)	222 (2)
50	Wholesale trade–durable goods	483	145	3.32	8 (7)	26 (9)	28 (4)	94 (5)
27	Printing and publishing	936	270	3.47	6 (8)	20 (10)	19 (6)	80 (6)
38	Instruments and related products	401	154	2.60	6 (9)	15	2	5
72	Personal services	725	129	5.64	5	27 (8)	9 (7)	49 (7)

*The mean number of potential asthmogen exposures per production worker (EXP/W) is presented for the entire country. The estimates have been rounded to the next thousand, and ranks are provided in parentheses for the appropriate category.

exposure to potential asthmogens was relatively high from the point of view of either total number of asthmogen exposures recorded (EXPS), asthmogen-exposed production workforce (EXP-PWF), or asthmogen exposures/worker (EXP/W), or any combination of these, and at any one of the three geographic levels.

National Data

At the time of the NOES, the Total Workforce (as defined above) in the United States was estimated to be 33,409,000 persons. The Production Workforce was estimated to be 19,572,000. The Asthmogen-Exposed Workforce was 7,864,000 workers (40.2% of the Production Workforce, 23.5% of the Total Workforce). The average number of recorded potential exposures per asthmogen-exposed worker was 4.43, and varied from 1.15 in SIC 41 (Local and Suburban Transportation) to 11.94 in SIC 44 (Water Transportation).

It can be noted that in some industries the number of production workers potentially exposed to one or more asthmogens (EXP-PWF) is high, but the number of potential exposures per worker (EXP/W) is relatively low: this is particularly noticeable in Health Services (SIC 80), Special Trade Contractors (SIC 17), Machinery, Except Electric (SIC 35), and Fabricated Metal Products (SIC 34).

In other industries the number of potential asthmogen exposures per worker is quite high, but the number of potentially exposed workers is comparatively small. Examples of this include Water Transportation (SIC 44), Transportation by Air (SIC 45), Miscellaneous Repair (SIC 76), and Primary Metal Industries (SIC 33).

Furthermore, in some industries both the number of potentially exposed workers and potential exposures per worker are relatively high. This is seen in Apparel and Other Finished Products (SIC 23), Transportation Equipment (SIC 37), and Food and Kindred Products (SIC 20). The

garment industry (SIC 23) is also notable because it has the highest proportion of production workers (80%) and one of the highest proportions of asthmogen-exposed workforce to total workforce (47%).

With respect to the observed use of protective measures (and as a specific illustration), Table II presents the average number of unprotected potential exposures to asthmogens among production workers in SIC 23 by 1980 census occupation code. The ten occupations listed account for an estimated 40,000 production workers (8.7% of the production workforce in SIC 23). By comparison, the number of Textile Sewing Machine Operators (census occupation code 744) potentially exposed to asthmogens (with or without exposure control) was estimated to be 291,000 (i.e., 62.9% of the total national production workforce in SIC 23). The average number of potential asthmogen exposures for occupation code 744 in SIC 23 was 9.65. However, a total lack of protection was observed for only 19.7% of the production workers in this occupation, for an average number of unprotected potential asthmogen exposures of 1.90 per worker. The reader may recall that the average number of potential exposures per production worker in SIC 23 at the national level was 10.37 (see Table I).

Connecticut Data

Table I includes the ten industries with the highest estimated number of production workers potentially exposed to asthmogens in Connecticut. Note that four of the top ten industries are different from those listed at the national level. That would suggest that Printing and Publishing (SIC 27), Measuring Instruments (SIC 38), Wholesale Trade of Durable Goods (SIC 50), and Business Services (SIC 73) might be expected to have more significance in terms of asthmogen exposures in Connecticut than in the nation as a whole. Finally, the table shows the ten Connecticut industries where the largest number of potential asthmogen exposures would be expected to take place.

New York City Metropolitan Area Data

Table I presents the ten industries with the largest production workforces potentially exposed to asthmogens (EXP-PWF) and those with the largest number of potential asthmogen exposures (EXPS) in the New York City metropolitan area.

In contrast with national data, New York City data point to relatively high numbers of potentially exposed workforces in Business Services (SIC 73), Wholesale Trade of Durable Goods (SIC 50), Printing and Publishing (SIC 27), and Personal Services (SIC 72). The most notable difference with respect to Connecticut is the relative importance of potential asthmogen exposures in the garment industry (SIC 23) in New York City (as is also the case at the national level).

TABLE II. Average Estimated Unprotected Potential Asthmogen Exposures Per Production Worker in the Apparel and Other Finished Products (SIC 23) Industry*

Occupation code	Description	Unprotected asthmogen exposures
449	Maids and Housemen	37.68
873	Production Helpers	28.00
777	Miscellaneous Machine Operators	21.97
328	Personnel Clerks (exc. Payroll and Timekeeping)	21.07
779	Machine Operators	13.99
765	Folding Machine Operators	11.73
719	Molding & Casting Machine Operators	9.16
259	Sales Representatives	9.01
676	Patternmakers, Lay-out Workers & Cutters	6.99
796	Production Inspectors and Examiners	6.96

*The overall estimated average for unprotected potential asthmogen exposures per production worker was 10.37 (see Table I).

DISCUSSION

An important deficiency in occupational asthma epidemiological research has been the lack of adequate data on the prevalence of exposures. In this work, data from the NOES have been processed to provide that information.

The analysis presented here reveals that 23.5% of the workforce employed in industries covered by the Occupational Safety and Health Act of 1970, and targeted by the NOES survey, were potentially exposed to occupational asthmogens. Industries with production workforces potentially exposed to a relatively high number of asthmogens included Water Transportation (SIC 44), Apparel and Other Finished Products (SIC 23), Air Transportation (SIC 45), Miscellaneous Repair Services (SIC 76), and Primary Metal Industries (SIC 33).

Surveillance for occupational asthma (as in general occupational health) should have two components: public health (medical), and hazard surveillance [Markowitz, 1992]. Inferences from medical (physician-based) surveillance for occupational asthma have tended to focus attention on occupational asthma caused by a small group of better-characterized agents, such as isocyanates or Western red cedar dust [Cullen, Cherniack, 1989; Meredith et al., 1991; Reilly et al., 1994; Gervais, Rosenberg, 1986]. At present, there are very limited prospectively collected data on the incidence of occupational asthma in workers exposed to certain selected agents [Weill et al., 1981]; even more limited are population-based incidence data [Reilly et al., 1994; Meredith et al., 1991].

This analysis of NOES hazard surveillance data corroborates some of the expectations of the large number of

potential asthmogen exposures in industries where well-known occupational asthmogens like isocyanates are widely used (e.g., SICs 17, 36, 37, and 45). However, it also points to some risk of occupational asthma in several industries where this risk has been less well recognized. For example, the potential risk for occupational diseases and disability in the garment industry (SIC 23) was not related to asthma [Brisson et al., 1989] until two recent preliminary reports [Friedman-Jiménez et al., 1994; Herbert et al., 1989]. The number of potential exposures (total and per production worker) estimated from the NOES data suggest that occupational asthma may deserve further investigation as a cause of disease in that industry. With respect to the Health Services industry (SIC 80), recent (1988–1992) data from SENSOR (Sentinel Event Notification System for Occupational Risks) in New Jersey reported 12.3% of the occupational asthma cases from that industry [Reilly et al., 1994].

Analysis of the NOES data also provides information about the observed use of exposure controls in different industries and occupations. For example, relatively intensive use of exposure controls was observed in SICs 44 and 76, which have a high average number of asthmogen exposures per worker. In contrast, in SIC 23 (Apparel and Other Finished Products), which also has a high average number of potential exposures per worker, lack of protection was frequently observed, although only for some specific occupations. With carefully defined assumptions, job-exposure matrices may be derived from data like these [Greife et al., 1995] and such work is currently being done by our group.

Exposure to an asthmogen is only one of several factors in the causation of occupational asthma. Additional factors may include the concentration of the agent, its physical characteristics, the length and intensity of occupational exposure, the use and appropriateness of any protective device (personal or engineered), and possibly individual susceptibility factors [Venables, 1987]. It is therefore not surprising that estimates of asthma risk resulting from exposure to individual occupational asthmogens vary widely, and are frequently unknown [Chan-Yeung, Lam, 1986].

The estimates that were generated from this study are probably conservative. The list of asthmogens is likely to exclude currently unrecognized agents. That list was developed for surveillance purposes, and the analysis presented here is accordingly relevant to the prevalence of potential exposures to asthma-causing and aggravating agents.

We considered only the production workforce because it was the subject of most of the observations and because it can be reasonably presumed to be more subject to asthmogen exposures than clerical and administrative personnel employed in those industries. The total number of exposures per industry and asthmogen-exposed workforce were calculated because they may suggest guidelines for better targeting of surveillance efforts. The estimates assume similar working conditions to those that existed at the time the survey was conducted (early 1980s). Changes have occurred in industry (health and safety, new production technologies and agents, geographic location, etc.) that may have affected some of the findings reported here.

In general, we believe that nearly all previously discussed [Greife et al., 1995] potential limitations of the data were taken into account. Further analytical work based on NOES data is in progress, which includes cross-referencing with other databases containing more detailed exposure information, as well as the use of a number of previously published ‘risk ranking‘ indices [Pedersen et al., 1983; Froines et al., 1986].

Finally, this work underlines the importance of ongoing occupational hazards surveillance at the national level, even more so in view of the increasing number of new workplace exposures, a changing workforce distribution, and the recognized need for better targeting of resources. The NOES data, as demonstrated here, are a unique source of information about potential exposures to asthmogens by occupation and industry and can be used to obtain estimates at the local level and to detect differences in exposure prevalence patterns. Better targeting of medical and public health surveillance resources at the local level could result from a wider knowledge (and ongoing updating) of those exposure prevalence estimates and patterns.

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