VII. Hazard Surveillance at NIOSH

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Introduction

The goal of hazard surveillance is to develop information that contributes to the prevention of occupational disease and death. Effective primary prevention can perhaps most logically be achieved by early detection of an agent's potential for harm, identification of the occupational groups exposed to the agent, and dissemination of this information to those who are in a position to interrupt the disease process. "Primary prevention connotes the exclusion, cessation, or limitation of exposure so that the disease process is not initiated."[1] Because surveillance of hazards does not rely on detecting patterns of excess disease or death, it is—at least in theory—a particularly promising technique for identifying targets for intervention before the disease process has begun.

It would be unreasonable to expect universal agreement on the question of what sort of information should be developed by a hazard surveillance program. Indeed, the answer depends substantially on the ultimate usage envisioned for the information. One possible strategy for hazard surveillance might focus on locating and monitoring groups of workers who are exposed to agents with well-known adverse health effects. This would permit keeping exposure levels low enough to prevent illnesses from developing. A second and distinctly different strategy for hazard surveillance might focus on discovering previously unrecognized relationships between exposure and disease. This can be done by constructing comprehensive inventories of potential exposure agents found to be associated with occupational groups and using these data in conjunction with sources of toxicologic or epidemiologic information. Hazard surveillance programs designed to monitor a few well-understood hazards are frequently found in the context of programs designed to assess compliance with existing exposure standards (e.g., OSHA environmental monitoring to identify violations of the lead standard). Hazard surveillance efforts designed to discover new agent-disease links are more likely to be elements of research programs that identify exposure agents or occupational groups for epidemiologic studies to provide a base for developing future standards or regulations. Perhaps not unexpectedly, the hazard surveillance program at NIOSH, which this paper describes, has evolved along the lines of the latter (discovery) strategy.[2]

The adequacy of such a hazard surveillance program can be judged by how successfully it answers certain basic questions:

- What exposure agents are found in the workplace?
- What is being done to control these exposures?
- Which agents affect the most workers?
- Where are exposed workers found?
- What health effects might these exposures produce?
- How are occupational exposures changing over time?

Even in a world bounded by practical realities, defining and aspiring to an ideal is often useful. Although such an optimum goal may, in fact, be unattainable, the task of designing strategies to approach it and the process of measuring success is simplified when a clear picture of the "perfect world" is available. In forming a concept of the ideal system for surveillance of occupational health hazards, we might envision having current and continuous information available for analysis on the exposure levels of all chemical, physical, and biologic agents for all working men and women in the United States. For each of these agents, we would also have detailed information on human dose-response relationships and the interactive effects of multiple exposures. For those situations where engineering controls or personal protective devices were in use, we would know the degree to which exposures were being attenuated by those controls or devices. Ideally, our capability for analyzing this mountain of data would be limitless, and our ability to disseminate intelligence would be unfettered.

Unfortunately, substantial real-world obstacles usually prevent the achievement of this optimum state. The array of chemical, physical, and biologic agents in the nation's five million workplaces is staggering, and the mix is constantly shifting as new agents are discovered and new processes are introduced. Even identifying a particular exposure agent can be a formidable task because component information on exposure agents that occur as formulated products is often obscured by trade names, common names, or ambiguous terms. Most hazard surveillance systems use the Standard Industrial Classification (SIC) coding scheme to classify facilities into industrial groups. The SIC coding system, however, was not designed to classify industries on the basis of common exposures. Consequently, a high degree of variability may exist among facilities that share an SIC code, and this may impair the inferential value of data collected from a small number of establishments.

Additional problems await persons who wish to obtain hazard surveillance information that includes environmental sampling data. Sampling and analytic methods exist for only approximately 500–600 agents,[3–10] but most studies suggest that more than 10,000 different potential exposure agents are present in the occupational environment. Costs of collecting

NOTE: Author affiliations and addresses are listed on p. 7.

and analyzing environmental samples vary widely, depending on the agent and sampling strategy, but probably average at least $50 per analyte. Human dose-response data exist for only a handful of exposure agents, and toxicologic information from animal studies is lacking for most chemical agents found in the workplace.[11]

The difficulties associated with hazard surveillance and the deficiencies of existing data systems should not, however, deter efforts to pursue a vigorous program. When surveillance systems for cause (hazard) and effect (disease) are integrated and linked, the potential for discovery is enormous. For some hazards (e.g., asbestos), the disease outcome is well-defined; in these cases, the role of hazard surveillance is to locate occupational groups exposed to the known disease-causing agents so that controls or other intervention measures can be implemented. However, the vast majority of workplaces present a complex picture of mixed exposure agents, diverse symptoms, and incomplete data. In such real-world situations, the combined efforts of hazard and disease surveillance are required to solve the puzzle. Thus, surveillance of hazards and of diseases cannot realistically proceed in isolation from each other, at least for research purposes.

History

The history of efforts at NIOSH for hazard surveillance is outlined here to provide a summary of major project initiatives that took place during the years following passage of the Occupational Safety and Health Act of 1970. We will not attempt to describe or evaluate the activities or strategies of other federal agencies, states, or the private sector in carrying out hazard surveillance.

1970–1975:

The Occupational Safety and Health Act of 1970 (PL 91–596) gave NIOSH several broad mandates. The first director of NIOSH created seven implementation task forces to assist him in meeting these new mandates. The task forces consisted of members drawn from the public and private sectors to study selected aspects of the NIOSH mission and to recommend strategies for responding to legislative directives. The Task Force on Hazard and Disease Monitoring filed its report on February 16, 1971, and recommended that NIOSH undertake a National Occupational Hazard Survey to determine the extent of exposure to occupational hazards and the degree to which such exposures were being controlled. The results of such a survey would aid in setting up priorities for the NIOSH research agents. Such a survey would also replace the National Surveillance Network (NSN) that was in place at the time the OSH Act was passed. The NSN consisted of cooperative agreements with state occupational health agencies under which results of the states' workplace inspections would be shared with NIOSH. In turn, NIOSH would automate and analyze the data and supply annual reports back to the cooperating states. No more than 10 states participated in the NSN at any time, and deficiencies existed in the scope of coverage and the standardization of techniques for data collection.

The National Occupational Hazard Survey (NOHS) was initiated in February 1972 with a team of 20 field surveyors. Over the next two and one-half years, data were collected in a sample of 4,636 establishments that employed nearly 900,000 workers in 67 different metropolitan areas. Facilities were selected for the survey to include all industries covered by the OSH Act, and the sampling scheme was specifically designed to permit development of national estimates from sample results. Information was collected for each establishment surveyed on the type and extent of industrial hygiene and safety engineer services, medical and health care provisions, status of health records and physical examinations of employees, policies for personal protective equipment, type of workers' compensation insurance, and injuries and illnesses reported on OSHA Form 102. A complete tour of each establishment was then undertaken, during which the surveyor recorded job titles for all employees and listed all potential exposure agents, including trade-named products. The duration of each potential exposure was classified as full- or part-time, and the types of personal protective equipment or engineering controls in use were recorded. NOHS eventually resulted in a list of nearly 9,000 different potential exposure agents. Approximately 86,000 different trade-named products were identified as potential exposures. This necessitated a large-scale data-gathering activity following the field phase of the NOHS to obtain detailed component information from the manufacturers of the trade-named products. Satisfactory component information was eventually compiled for approximately 72,000 products.[12–16]

1975–1980:

The NOHS database found immediate and widespread applications in many phases of NIOSH and other federal research. A major purpose of NOHS was to provide, for the first time in this country, answers to the questions listed in the Introduction of this paper. Before NOHS data were available, no national database existed for estimating the number of workers potentially exposed to chemical, physical, or biologic agents. Similarly, the extent of control technology being used was known only for a nonrepresentative sample of workplaces. NOHS data also found extensive use as one input for determining priorities for OSHA inspections. It was referenced in NIOSH criteria documents and consulted as a source of information on chemical ingredients for over 70,000 trade-named products found in US worksites.

One notable application was the use of NOHS data in combination with data from the NIOSH Registry of Toxic Effects of Chemical Substances (RTECS) to produce a model capable of systematically identifying high-risk employee groups.[3–10] Because NOHS does not provide direct information on health effects of the 9,000 potential exposure agents, it was logical to link the file to RTECS, which provides extensive information on the results of toxicologic studies on many agents. By using RTECS data to create severity indices for NOHS agents, it was possible to construct overall severity indices for particular occupations or industries, based on potential exposure agents associated with that group. The output from such a linking and modeling process is a list of industries or occupations, rank-ordered on the basis of potential health risk. The model is designed to permit liberal production of custom outputs based on criteria supplied by the user. It is possible, for example, to focus the model on only chronic health effects, or to combine all effects in a weighting scheme chosen by the user. The outputs from such a model have obvious value for those who wish to identify groups of workers with elevated potential for health risk from occupational factors or to explain increases in disease outcomes among occupational groups.

Although the RTECS file contains data on an impressive array of agents, fewer than 2,000 of the 9,000 potential exposure agents recorded during NOHS were listed in RTECS. In an effort to expand the coverage of the NOHS-

RTECS model, NIOSH supported research into a system designed to apply structure-activity principals to the NOHS compounds not listed in RTECS. As a result of this effort, NIOSH obtained a predictive toxicology system that is capable of generating estimates of potential toxicity for four different endpoints (acute toxicity, carcinogenicity, teratogenicity, and mutagenicity) for chemical agents that can be described structurally and that meet certain other eligibility requirements.[17] Other applications of the system as a hazard surveillance tool, in addition to its role in improving the NOHS-RTECS model, include providing estimates of an agent's potential toxicity even before animal testing has been completed.

The NOHS file was also used during this period to depict the presumed geographic location of occupational groups potentially exposed to selected agents. By linking the NOHS file to a national industrial demographic file, it was possible to produce computer-generated maps of the nation or selected states or regions which would graphically portray county-specific potential exposure patterns. The output characteristics of these maps could be adjusted to show the geographic spread of establishments or employees, or population-based rates by county for potentially exposed groups. These heuristic techniques were intended for possible applications in generating or testing hypotheses.[18–20]

Two other approaches for obtaining hazard surveillance data were explored during this period. First, contacts were made with many major national and international unions to help establish a collaborative relationship under which the unions would compile detailed lists of agents to which their members were potentially exposed and forward this information to NIOSH. NIOSH would then search the nonproprietary portion of its files on product-ingredient information to identify ingredients of any items on the list that were trade-named products. Then NIOSH would supply information on the possible toxic properties of agents for which such information was available. Presumably, the unions would then be better able to bargain for improved health and safety programs for their membership. Although this program is still in existence, the number of participating unions has declined.

The second strategy targeted employers as sources of hazard surveillance data. Through the Cooperative Exposure Survey (CES), employers applied the observational survey techniques used in NOHS to inventory the potential exposure agents in their own establishments.[21] A self-survey kit was assembled, including forms and instructions necessary to conduct an establishment survey. When NIOSH received the completed forms, it would review the list for any trade-named products for which ingredient information was available. In addition, NIOSH would identify agents for which exposure standards existed or for which toxicologic information could be obtained and send such information back to the employer with any other NIOSH publications that contained appropriate subject matter. Both of these data-gathering strategies had obvious and known deficiencies, especially regarding the production of representative, reliable data. They were conceived as alternative surveillance techniques, designed to be more fully explored as components of a hazard surveillance program if NIOSH could not conduct field-based national surveys like NOHS.

Early in 1976, the Director of NIOSH requested formation of a NIOSH Task Force on Occupational Health Surveillance to address the problem of establishing a viable surveillance program for the Institute. An eight-member group composed of recognized experts in occupational health and surveillance met several times over a period of four months and, in August 1977, produced a report (unpublished) for the Director. Although much of this "Report of a Task Force on Occupational Surveillance" dealt with strategies for disease surveillance, a key recommendation was that NIOSH conduct a second national hazard survey modeled after NOHS. The Task Force reasoned that NOHS provided valuable inputs to the NIOSH research mission, and because the data were aging, an update was necessary. Accordingly, plans for a second national survey were initiated.

1980–Present:

On November 1, 1980, the field phase of the National Occupational Exposure Survey (NOES) was initiated.[22] A total of 4,490 establishments employing 1.8 million workers were surveyed during the field phase, which ended in May 1983.[23] The survey was conducted in 98 different metropolitan areas and covered all types of industry except mining; certain agricultural sectors; federal, state, and local governments; financial institutions; wholesale and retail trade; and certain professions. NOES was patterned very closely after NOHS, although improvements were made in the data automation procedures. Questions were added on gender of potentially exposed employees, and selected chronic trauma events were added as recordable potential exposure agents. As in NOHS, approximately 70 percent of all potential exposure agents were recorded in the form of trade-named products. More than 100,000 different trade-named products were recorded, and efforts continued to obtain component information. The data from NOES are provisional until such time as a satisfactory proportion of the trade-named products are resolved.

As of June 1988, approximately 50 percent of the trade-named products had been resolved. More than 10,000 different potential exposure agents have been identified, and this total will expand as resolution of trade-named products continues. Because NOHS and NOES both collected data in much the same way, analysis of temporal changes between the two surveys will be possible. Approximately 30 questions asked during the interview phase of each survey are similar enough to support this type of trend analysis, and certain of these analyses, which do not require complete product ingredient information, have begun.[24]

NIOSH reformatted the NOHS file as a job-exposure matrix (JEM) to facilitate its use in epidemiologic applications.* Data from establishments in the same industry were combined to create a three-level hierarchical file. Each level of classification is nested within the previous one, beginning at the industry level. Thus, the three levels of classification of JEM are industry, occupation within industry, and potential exposure agent within occupation within industry.

Two major epidemiologic applications are expected. The first application is to increase the specificity of potential exposures. Many case-control studies rely solely on the industry and occupation descriptors found in records that were not designed for research purposes, e.g., death certificates. It appears from the work of Sieber* that by using JEM, cases (and controls) can be subdivided further to identify those occupational groups within an industry where potential exists for exposure to a hazard of interest.

*Sieber WK: Use of a job exposure matrix in epidemiologic analyses. Submitted manuscript.

The second application is to use JEM to expand the utility of the list of Sentinel Health Events (Occupational) (SHE[O]).[25] The original SHE(O) list compiled by Rutstein, *et al*, included industries and occupations that were linked in the literature to a hazard associated with an occupationally related disease. Other industries and occupations might also have the same hazard. Information from JEM now makes it possible to identify this expanded set of workplaces. A recent article by Lalich and Schuster describes the analysis of death certificates currently underway using the expanded SHE(O).[26]

In the same manner, JEM data have been used in conjunction with other national databases, e.g., the National Center for Health Statistics Household Interview Survey (NHIS) and the National Health and Nutritional Examination Survey (NHANES). By linking self-reported hearing loss from NHIS to noise levels measured by NOHS, estimates were made of the joint role of aging and noise in the workplace.[27] Using the NHANES data with a list of workplaces where NOHS indicated a potential exposure to lead, NIOSH investigators found significantly increased blood lead levels in a nationally representative sample of workers potentially exposed to lead.[28]

NIOSH obtained the OSHA Integrated Management Information System (IMIS) files to augment and complement other hazard surveillance databases. IMIS contains the results of OSHA health inspections since 1979 for those states in which OSHA compliance officers operate. The most obvious contribution of these data is the completed environmental sampling and analytic results contained in the file.[29] Although approximately 500 agents are regulated by OSHA, 75 percent of the IMIS data dealt with only 15 compounds. More than 15 percent of all the OSHA samples are collected for lead or lead compounds. Because the majority of OSHA's compliance inspections are conducted in response to complaints or fatalities, the file is not intended as representative, nor can reliable inferences be made to national statistics. A companion paper in this monograph (chapter VI) addresses the feasibility of establishing links between the IMIS file and NOHS/NOES, and JEM.

During this period, NIOSH also began investigating the potential role of computer-based, in-plant surveillance systems in a national hazard surveillance strategy. The emergence of low-cost computers, coupled with increased requirements for surveillance and record-keeping under OSHA's Hazard Communication rule, has resulted in a variety of software products that permit employers to collect, store, and analyze data on potential exposure agents, environmental sampling, and medical testing and treatment of employees.[30,31] Potentially, such systems can produce data for hazard and disease surveillance that supplement observational data collected in national surveys like NOHS and NOES.

Typical Uses of Hazard Surveillance Data

NIOSH receives an average of 200 requests per year for data from NOHS or NOES. Table 1 shows a profile of users over a typical 12-month period.

Because the sample of establishments for NOHS and NOES was designed to permit the development of national statistics from the survey data, estimates can be generated of the number of employees potentially exposed to any of the approximately 9,000 chemical, physical, and biologic agents, and industries and occupations can be identified where those potential exposures occur. Thus, this database is particularly useful as a source of information for assigning priorities to toxicologic and epidemiologic research. In fact, potential exposure estimates from NOHS were used extensively as one ingredient of the algorithm by which NIOSH assigned priorities for topics for its Criteria Documents. The database is also used to profile potential exposure agents associated with particular industry or occupational groups to help develop or sharpen hypotheses suggested by morbidity or mortality surveillance activities. The file of product ingredient information, which was developed in conjunction with the surveys, can also be used as a hazard surveillance tool in its own right. For example, if new toxicologic evidence emerges concerning a particular agent, the product ingredient file can be queried to display all products that contain this agent (and their manufacturers). This information can then be used to identify occupational groups potentially exposed to the agent (manufacturing site and purchasers of the product) for appropriate intervention strategies. Since NOHS was completed, the information it has produced is frequently referenced by Congress, scientific literature, the national press, and in professional conferences. It has provided important input to OSHA's compliance activities by providing the base on which a model for targeting discretionary health inspections was built and implemented. The data were also prominently referenced in the preamble of OSHA's Hazard Communication rule. The chemical selection procedures of the Environmental Protection Agency (EPA), the National Toxicology Program, and the Bioassay and Epidemiology programs of the National Cancer Institute have all made use of NOHS data.

TABLE 1—User Profile for NOHS/NOES Data Requests (July 1986–June 1987)

Source	% of Requests
NIOSH	45.7
Industry*	23.3
Other federal agencies	14.7
State government	7.8
Academia	4.7
Foreign	2.3
Private citizens	1.6

*Includes government contractors, attorneys, and information vendors.

The NOHS and NOES databases are unique because of the wide range of potential exposure agents covered, the representative nature of the sample of establishments, and the approach used to clarify potential exposures to trade-named products. The data play an essential role in virtually any intervention strategy; precisely this sort of prior intelligence on potential exposures is necessary to guide and support the full range of intervention strategies that should follow. When scarce resources must be directed toward problems of the highest priority, NOHS and NOES continue to supply important input to a complex decision-making process.

Future Directions

Periodic, large-scale, national surveys like NOHS and NOES have substantial advantages when compared with alternate sources of hazard surveillance data. The data they produce on many potential exposure agents can be generalized and will support the analysis of temporal trends. The most apparent disadvantages are the cost and the lack of environmental sampling data. Currently no specific plans are underway to conduct a third national survey, although such an approach will undoubtedly be considered with other options at the appropriate time.

An alternative to the periodic survey is a continuing survey that sequences specific segments of industry for survey each year; the survey becomes "complete" after all relevant industries have been surveyed, and then the cycle repeats. A continuing, cycling design has certain advantages because the data are always reasonably current, resource requirements are more predictable and spread evenly over many years, and start-up and phase-out problems are eliminated. The National Occupational Health Survey of Mining (NOHSM) currently in progress is of this type; mines and mills are selected based on commodity groups and sequenced accordingly. The entire survey will require an estimated six years to complete. Retaining surveyors over the course of such a survey is difficult, and costs are at least as high as with periodic surveys.

Another possible strategy would be simply to augment the centerpiece NOHS and NOES databases with smaller special-purpose surveys as needed. Examples of sectors that would complement the existing data are agriculture, small businesses, and emerging technologies. It may even be possible to construct special-purpose surveys that would develop environmental sample data in a smaller set of facilities, perhaps drawn as a subsample of the NOES establishments.

Improving the use of existing databases for hazard surveillance will potentially broaden the capabilities of the hazard surveillance program at very little additional cost. The NIOSH Hazard Evaluation and Technical Assistance activity responds to approximately 500 requests per year. Many of these requests evolve into on-site toxicity determinations with environmental sampling and cross-sectional medial screening of employees. Even though the development of inferential statistics may not be possible from such data, they can function like the OSHA IMIS file as an additional source of information for associating exposures with occupational groups. Tracking the development of data generated by EPA under the Emergency Planning and Community Right to Know Act of 1986 and by the Hazard Communication rule enforced by OSHA will also be important.

Opportunities are potentially great for synergistic interaction between activities in both hazard and disease surveillance.[27,28] The NOHS and NOES databases can be used to expand the number of industries and occupations known to be associated with sentinel health events of possible occupational origin.[26] The systematic use of JEM in the epidemiologic analysis of large data sets can potentially identify previously unrecognized associations between exposure and disease.

Improved dissemination of hazard surveillance data already at hand is a particularly promising strategy for the future. Current strategies for disseminating surveillance data rely heavily on NIOSH Technical Reports, journal articles, presentations at conferences and other meetings, and customized reports developed in response to requests from potential users. Although these strategies do result in a considerable flow of information to recipients capable of using it, substantial opportunities to broaden the base of information available exist in recent advances in the technology of information transfer. In general, surveillance data are fundamentally different from other species of data that NIOSH disseminates. In most cases, the datasets are very large and a commensurately large number of potential analyses are possible. For example, the NOHS and NOES datasets each produced databases of some five million records. Results from these surveys have been widely published, but substantial analytic possibilities still remain. These have been inadequately explored, particularly by researchers outside NIOSH, primarily because of the practical difficulties in transferring files of this size and complexity. Specialized subfiles have been created from NOHS (e.g., JEM) and distributed on computer tape to a wide variety of users, but a large portion of the potential market for these data remains underserved.

Rapid advances in the technology for handling information make it possible to consider a broad array of innovative techniques for disseminating large amounts of data to many users.[32] The proliferation of personal computers makes possible the dissemination of information on floppy disks, and many users of personal computers also possess modems for accessing datasets, either by connecting to mainframe computers or through electronic bulletin boards. Several government agencies have begun to make data available through such channels (Bureau of the Census, Bureau of Labor Statistics, etc.). The capacity of storage media is also improving with the emergence of optical techniques like read-only compact disks (CD ROM), which are being used to disseminate extremely large data files. Disseminating information accomplishes more than simply educating the recipient; it builds channels through which continuing communication can occur. The more channels are created, the easier it will be to obtain current intelligence on occupational hazards and their health effects.

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