American Journal of Industrial Medicine 11:329-342 (1987)

# Death Certificate-Based Occupational Mortality Surveillance in the United States

**Robert Dubrow, MD, PhD, John P. Sestito, MS, Nina R. Lalich, MSPH, Carol A. Burnett, MS, and Joyce A. Salg, PhD**

Surveillance of cause-specific mortality patterns by occupation and industry through the use of death certificate records is a simple and relatively inexpensive approach to the generation of leads as to potential occupational disease problems. Researchers from the National Institute for Occupational Safety and Health (NIOSH) have been working with the National Center for Health Statistics, other federal agencies, and state health departments on a number of programs to foster the development of standardized, routine coding of occupation and industry entries on death certificates by state health departments. Thirty-one states and the District of Columbia are now doing such coding. These data are being analyzed currently by investigators at NIOSH and at individual state health departments for the purpose of hypothesis generation on occupation–disease relationships. The proportionate mortality ratio method is the predominant method being used, as appropriate denominator data are not generally available. This type of surveillance is particularly useful for the study of occupation and industry groups for which it is difficult to assemble cohorts, such as groups that are predominantly non-union and in small workplaces. Limitations of this surveillance include its inappropriateness for monitoring those occupational diseases which are not often fatal, and the limited scope and accuracy of death certificate information.

**Key words: occupational disease, occupational surveillance, mortality surveillance, surveillance, death certificates**

## INTRODUCTION

The World Health Organization has defined disease surveillance as "a concerted attempt to keep under continuous observation all the factors that contribute significantly to the occurrence of disease in human populations" [World Health Organiza-

Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

This paper is an expanded version of a working paper presented by Dr. Dubrow at the World Health Organization, Regional Office for Europe, Occupational Health Office, Consultation on Linkage of Occupational Exposure Information With Morbidity and Mortality Register Data meeting, November 11-13, 1985, in Copenhagen, Denmark. The views expressed are not necessarily those of the World Health Organization.

Address reprint requests to Robert Dubrow, MD, PhD, Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, Mail Stop R-18, 4676 Columbia Parkway, Cincinnati, OH 45226.

Accepted for publication September 22, 1986.

tion, 1968]. Researchers at the National Institute for Occupational Safety and Health (NIOSH) are utilizing and promoting a number of different approaches for the surveillance of work-related disease, disability, and death. Most of these approaches are aimed toward adapting and using existing relevant data systems, including death certificate records [Milham, 1976; Petersen and Milham, 1980; Gute, 1981; Frazier and Coleman, 1983; Milham, 1983; Dubrow and Wegman, 1984a,b; Brockert et al, 1985; Pennsylvania Department of Health, 1985; Kelley and Gute, 1986; MacCubbin et al, 1986], the Social Security Administration Continuous Disability History Sample [Kennedy et al, 1980; Frazier and Coleman, 1983; Osborne and Fischbach, 1985; Fischbach et al, 1986a,b], the National Health Interview Survey [Kaminski and Spirtas, 1980; Frazier and Coleman, 1983], hospital discharge summaries [Burkart et al, 1978, 1981; Burkart, 1983], hospital- and population-based cancer registry records [Decouflé et al, 1977; Lassiter et al, 1980; Whorton et al, 1983], workers' compensation claim records [Frazier and Coleman, 1983; Seligman et al, 1986], and birth certificate and fetal death records [Shilling and Lalich, 1984] (to monitor adverse reproductive outcomes). In addition, efforts are being made to promote the reporting of specific occupational diseases, such as pneumoconioses and heavy metal poisoning, at the state level.[1]

Surveillance of cause-specific mortality patterns by occupation and industry through the use of death certificate records is one important component of the nationwide surveillance system that NIOSH is attempting to develop. In contrast to the decennial occupational mortality studies published by the Registrar General in England and Wales [Registrar General, 1978], only one national occupational mortality study has been done in the United States—for the year 1950 [Guralnick, 1963]. In addition, a recent study described occupational mortality patterns among a cohort of United States veterans [Walrath et al, 1985]. As of 1984, published occupational mortality surveillance studies had been performed in only four states: Washington (1950–1979) [Milham, 1976, 1983], California (1959–1961) [Petersen and Milham, 1980], Rhode Island (1968–1972) [Gute, 1981], and Massachusetts (1971–1973, cancer only) [Dubrow and Wegman, 1984a,b]. Only two of the United States studies had studied women (whites only) [Gute, 1981; Milham, 1983], and only the 1950 study included non-white men.

Thus, death certificate records present a largely untapped resource for occupational mortality surveillance in the United States. This paper describes efforts which have been underway over the past 7 years to tap this resource. Emphasis is placed on the use of occupational mortality surveillance for the generation of leads as to potential occupational disease problems.

## COLLECTION AND CODING OF OCCUPATION AND INDUSTRY INFORMATION ON DEATH CERTIFICATES

Information on usual occupation ("kind of work done during most of working life, even if retired") and usual industry ("kind of business or industry") traditionally

[1]Mullan RJ: A proposal for state-based reporting of the pneumoconioses and mesothelioma. Presentation at the Conference of State and Territorial Epidemiologists, Minneapolis, MN, June 1984; Mullan RJ: Options for state-based reporting of occupational diseases. Presentation at the Conference of State and Territorial Epidemiologists, Madison, WI, June 1985.

has been collected on United States death certificates. Reporting of these data items has been shown to be relatively complete [Rosenberg et al, 1984]. Comparisons of statements on death certificates of usual occupation and industry with alternate sources of information on the decedent's work history generally have found agreement to be in the 60–80% range [Buechley et al, 1956; Wegman and Peters, 1978; Milham, 1983; Steenland and Beaumont, 1984; Swanson et al, 1984; Gute and Fulton, 1985; Schumacher, 1986]. However, until recently, most states have not coded the occupation/industry statements. As late as 1979, a survey indicated that only six states were coding both occupation and industry; five were coding occupation only; and one was coding industry only. There was no uniform coding system [Kaminski et al, 1981].

Researchers from NIOSH have been working over the past 7 years with the National Center for Health Statistics (NCHS), the Bureau of the Census, the Association for Vital Records and Health Statistics, and individual state health departments on a variety of programs to foster the development of standardized, routine coding of occupation and industry by state health departments, and the subsequent analysis of these data. Recently, the National Cancer Institute (NCI) has become involved as well. The following accomplishments have resulted from these collaborative programs:

1. The selection of the 1980 US Bureau of the Census occupational and industrial classification system as the standard system for occupation/industry coding of death certificates [Crouse et al, 1983]. This hierarchical system, which contains 503 unique occupation codes and 231 unique industry codes [US Bureau of the Census, 1982], is based upon the Standard Occupational Classification [US Department of Commerce, 1980] and Standard Industrial Classification [Office of Management and Budget, 1972] systems.

2. The publication of an instruction manual for industry and occupation coding for death certificates [US Bureau of the Census, 1984]. This manual adapts the US Census coding system, which was originally developed for census data, to the coding of death certificate data.

3. Training courses for state coders in both production and referral coding. Production coders perform routine coding, and refer problem cases to referral coders for resolution. As of June 1986, 133 production coders from 33 states, New York City, the District of Columbia, and Puerto Rico had been trained, as had 46 referral coders from 23 states and the District of Columbia.

4. Quality control resources for coding, provided to states by NIOSH and NCHS. Experienced NIOSH or NCHS coders recode a 2–10% sample (depending upon the size of the state) of the participating states' certificates. These codes are then compared with the codes that were assigned by the state coders.

5. The development of a computer edit program which detects records with invalid codes, occupation–industry code combinations that are in absolute violation of coding rules, and highly improbable occupation–industry code combinations. This program also identifies records in which the industry is not reported, but can be imputed from the occupation, and vice versa. For example, the industry of an elementary school teacher can be imputed to be elementary and secondary schools; that of a clergy can be imputed to be religious organizations.

6. The publication of a guide for reporting occupation and industry on death certificates [Byars, 1983]. Death certificate occupation and industry information is collected from the spouse or other informant by the funeral director. This guide provides instructions for obtaining complete and accurate information. Some states

are beginning to incorporate these guidelines into their instructional handbooks for funeral directors, and to conduct training programs for funeral directors and local registrars. A few states are beginning programs to query funeral directors or informants in order to correct incomplete or non-specific occupation or industry entries on death certificates.

7. The development by researchers at NIOSH of a proportionate mortality ratio analysis system computer software package for the purpose of routine analysis of occupational mortality data.[2] Several state health departments are using this system.

8. Several funding programs to aid state health departments in occupation and industry coding for death certificates. Six states (Rhode Island, Utah, Maine, New York, Pennsylvania, and North Carolina) have received funding through the Surveillance Cooperative Agreements Between NIOSH and States (SCANS) program. More recently other states have received funding from NIOSH through a state capacity-building cooperative agreement program, and NIOSH and NCI have provided funds to NCHS for support of coding by states.

9. The addition by NCHS, with support from NIOSH and NCI through an interagency agreement, of the death certificate occupation and industry statements to the routinely collected vital statistics data. In 1984, data were collected from Colorado, Georgia, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, Oklahoma, Rhode Island, South Carolina, Utah, and Wisconsin. Ohio and Tennessee were added to the program in 1985. In 1986, Indiana and Vermont are being added, while data from Nebraska are not being collected.

As a result of these various initiatives, 31 states and the District of Columbia are now coding death certificate occupation and industry entries (Table I).

## DATA ANALYSIS

NIOSH, NCHS, NCI, and individual state health departments all have plans for utilizing death certificate data for occupational surveillance purposes. Routine sex-

**TABLE I. Registration Areas That Code Death Certificate Occupation and Industry Entries**

| | | |
|---|---|---|
| Alabama | Maine | Oregon |
| Alaska | Massachusetts | Pennsylvania |
| Arkansas | Missouri | Rhode Island |
| Colorado | Nebraska | South Carolina |
| District of Columbia | Nevada | Tennessee |
| Georgia | New Hampshire | Texas |
| Idaho | New Mexico | Utah |
| Indiana | New York | Vermont |
| Iowa | North Carolina | Washington[a] |
| Kansas | Ohio | Wisconsin |
| Kentucky | Oklahoma | |

[a]Washington uses a modified version of the 1960 Bureau of the Census occupational and industrial classification system. This system is not compatible with the 1980 system.

[2]Dubrow R, Spaeth S. A proportionate mortality ratio analysis system for occupational mortality surveillance, manuscript in preparation.

and race-specific, age-standardized proportionate mortality ratio (PMR) analyses currently are being performed by investigators at NIOSH and at individual state health departments for the purpose of hypothesis generation. The PMR compares the proportion of deaths from a specific cause within a specific occupation or industry group with the proportion of deaths from that cause in a standard population, adjusting for age. The standard population usually used in these surveillance studies is the total population of decedents in the study.

While the PMR method can produce artifactual results, because it does not take population-at-risk into consideration and thus does not measure absolute cause-specific mortality rates, it seems to be adequate for hypothesis-generation purposes [Kupper et al, 1978]. Associations that would have been expected based upon prior knowledge, such as lung cancer in plumbers and cirrhosis of the liver in bartenders, are consistently found in surveillance studies using the PMR method. This provides evidence for its validity. As discussed below, appropriate denominator (population-at-risk) data for the calculation of mortality rates by occupation and industry are not generally available.

Another approach to death certificate-based occupational mortality surveillance, the monitoring of Sentinel Health Events (Occupational), is described elsewhere [Rutstein et al, 1983].[3]

Since 1980, NIOSH researchers have been engaged in cooperative activities (the SCANS and state capacity-building cooperative agreement programs) with several states to develop their occupational mortality surveillance capabilities. Data from Rhode Island for the years 1968–1978 and from Utah for the years 1959–1978 have been coded and analyzed for the purpose of hypothesis generation using the PMR method. Some of the results have been published [Gute, 1981; Brockert et al, 1985; Dubrow, 1986; Kelley and Gute, 1986] and a report has been written on research leads generated from these investigations [Dubrow and Burnett, 1985]. One such lead was an association between work in the printing industry and malignant melanoma [Dubrow, 1986]. PMR results have also been published from New York for 1980–1982 [MacCubbin et al, 1986], and Pennsylvania for 1983 [Pennsylvania Department of Health, 1985].

These PMR analyses of mortality patterns for many causes of death across many occupation and industry groups are descriptive studies generally performed with no specific *a priori* hypotheses. Given the large number of comparisons made in these studies, many of the observed statistically significant associations between work in specific occupations or industries and specific causes of death could be due to chance. Other associations could be due to confounding or biases. Each association should be evaluated with respect to its consistency with other epidemiological studies, its biological plausibility, and the likelihood that it could be explained by confounding or biases.

## ADVANTAGES AND USES OF OCCUPATIONAL MORTALITY SURVEILLANCE

Occupational mortality surveillance based upon death certificates presents the major advantage of easy accessibility to large numbers of death records, with infor-

[3]Lalich NR, Schuster LL: An application of the Sentinel Health Event (Occupational) concept to death certificates, submitted for publication.

mation on occupation, industry, and cause of death, that can be analyzed relatively simply and inexpensively. In a single study, information is obtained on cause-specific mortality patterns for many occupation and industry groups. This is particularly useful for occupation and industry groups that are difficult to study through the cohort approach. It is especially difficult to assemble cohorts of occupation or industry groups that are predominantly non-union and in small workplaces, such as automobile mechanics and farmers. Jewelry manufacturing workers in Rhode Island fit into this category. The excess bladder cancer found in the gasoline service station industry in the Washington State [Milham, 1976], Massachusetts [Dubrow and Wegman, 1984a,b], and Utah [Dubrow and Burnett, 1985] surveillance studies, and in a Canadian study [Howe and Lindsay, 1983] is an example of a finding in such an industry that should be followed-up.

Occupational mortality surveillance is also useful for the study of occupations or industries that are concentrated in particular geographical areas, such as the jewelry and textile industries in Rhode Island; the agriculture, mining, and primary metal industries in Utah; the lumber, wood products, and paper industries in Washington State; and the textile industry in South Carolina.

Some investigators have taken advantage of this geographical concentration by using death certificate data bases to study the mortality patterns of specific occupation or industry groups in particular states or localities, outside the context of general surveillance studies. The mortality patterns of female textile workers in North Carolina [Delzell and Grufferman, 1983]; farmers in Iowa [Burmeister, 1981], California [Stubbs et al, 1984], and North Carolina [Delzell and Grufferman, 1985]; jewelry workers in Attleboro, MA [Sparks and Wegman, 1980]; and leather workers in Brockton, Haverill, and Peabody, MA [Garabrant and Wegman, 1984] have been investigated in this manner. This type of study can be conducted in the context of occupational mortality surveillance. For example, as an outgrowth of the analysis of Rhode Island data, reports are being prepared on mortality patterns in the Rhode Island jewelry and textile industries.[4]

In determining the geographical concentration of occupation or industry groups, the key factor for the purpose of occupational mortality surveillance is the concentration of deaths. Thus, a relatively new industry that is a large employer in a particular geographical area may not have very many deaths associated with it. Most decedents who worked in the industry may not have been employed long enough for it to be considered their usual industry, and the age structure of those employed in the industry may be skewed towards the relatively young. On the other hand, there may be a large number of decedents concentrated in a geographical area who worked in an old, declining industry, as is the case with the textile industry in Rhode Island.

In spite of their limited number, occupational mortality surveillance studies have already served as an epidemiologic resource. Results of more analytical investigations of an occupation or industry group are often compared with those of occupational mortality surveillance studies as a check on their epidemiologic consistency. In addition, results of occupational mortality surveillance studies are often included as part of the rationale for conducting more analytical investigations. In some cases, the

[4]Dubrow R,Gute DM (1987): Cause-specific mortality among Rhode Island jewelry workers, submitted for publication; Dubrow R, Gute DM: Cause-specific mortality among Rhode Island textile workers, manuscript in preparation.

rationale for a follow-up investigation stems mainly from results from an occupational mortality surveillance study. For example, a cohort study of aluminum reduction plant workers [Milham, 1979], a PMR study of paper and pulp mill workers [Milham and Demers, 1984], and a follow-up investigation of electrocution among farmers [Helgerson and Milham, 1985] were prompted by results from the Washington State surveillance studies [Milham, 1976, 1983].

One relatively quick and inexpensive approach to following up surveillance leads is through a case-control study based upon death certificates. In such a study, the death certificate statements on occupation and industry of the decedents who died from the cause of death of interest are compared with those of a control group who died from other causes. Given that there is an *a priori* hypothesis, confirmation of the association being tested in this manner would greatly enhance its credibility. While this type of study is relatively crude, it can serve as an intermediate hypothesis-testing step between a descriptive PMR study and a more analytical study.

Two such studies that are currently in progress are case-control studies of stomach cancer and peptic ulcer in Rhode Island for the years 1979–1983. These studies were prompted by the finding of significantly elevated PMRs for both stomach cancer and peptic ulcer among females in the jewelry industry in Rhode Island during 1968–1978, [Dubrow and Gute, 1987] along with a previous report of elevated PMRs for these causes among male jewelry workers in Attleboro, MA [Sparks and Wegman, 1980].

In these case-control studies, information on the death certificate about the decedent's birthplace, the mother's maiden name, and the father's surname will be used to determine ethnicity, which will be controlled for in the analyses as a potential confounding variable. Decedents for whom peptic ulcer is mentioned as either a primary or secondary cause of death are being included in the peptic ulcer case series, as peptic ulcer is often mentioned as a secondary cause. This will improve both the power and precision of this study as compared with the PMR analysis, which did not take multiple causes of death into account.

As the data base for occupational mortality surveillance expands and more analyses are completed, the utility of occupational mortality surveillance as an epidemiologic resource should expand correspondingly. Results from different states can be pooled to amplify their usefulness, and can be reviewed systemically for promising leads [Dubrow and Wegman, 1983]. In addition, mortality surveillance might be useful for monitoring trends in some known occupational diseases, such as coal workers' pneumoconiosis in Pennsylvania and West Virginia. A sufficient experience base has not yet been developed to evaluate the utility of occupational mortality surveillance for this purpose.

## DENOMINATOR DATA

Appropriate denominator (population-at-risk) data for occupational mortality surveillance are currently virtually impossible to obtain. Such data are used for the computation of the cause-specific, age-standardized mortality ratio (SMR). This is

the ratio of the mortality rate for a specific cause in a specific occupation or industry group to the rate for that cause in the total population, standardized for age. The SMR is generally considered to be superior to the PMR as a measure of relative mortality [Decouflé et al, 1980].

The decennial census (1970, 1980, etc.) collects information on current occupation and industry on a sample of the population, as opposed to the usual occupation and industry information obtained on death certificates. If the difference between current and usual occupation and industry is ignored, SMR calculations could be performed using the age-specific numbers of persons at risk of death in each occupation and industry, as estimated from the census sample. This can be done for the age range of most working people (20–64) only, as most persons 65 years of age or greater are retired and do not have a current occupation and industry. This was the approach used in the 1950 United States study [Guralnick, 1963].

An assessment of comparability of occupation statements on census forms versus death certificates found 71% of the decedents to be in the same major occupational group and 61% to be in the same detailed occupational category [Kaplan et al, 1961]. In addition to this problem of the comparability of numerator and denominator, 70% of deaths in the United States among persons 20 years of age or greater occur among persons 65 years of age or greater [National Center for Health Statistics, 1985]. By excluding these individuals from the analysis, much valuable information is lost for chronic diseases or diseases with long latency periods which may have an occupational component to their etiology. For example, in 1980, 83% of bladder cancer decedents over age 19 were age 65 or greater, as were 78% of those who died from chronic obstructive pulmonary diseases and allied conditions and 79% of those who died from nephritis, nephrotic syndrome, and nephrosis [National Center for Health Statistics, 1985]. Some portion of each of these diseases is known to be related to occupational exposures.

Two alternative approaches could be taken for calculating SMRs for occupations and industries using census and death certificate data that would avoid the above mentioned problems. In one approach, entries would be added to the census questionnaire to solicit information on the usual, as well as the current, occupation and industry, thus making the numerator and denominator data comparable and allowing persons greater than 64 years of age to be included in the analysis. Decennial studies (either for the census year alone or for the 3 or 5 years surrounding the census year) could then be performed. A similar proposal was made for the 1980 Census [National Center for Health Statistics, 1977], but never implemented.

The other alternative approach for computing SMRs, which has been proposed previously [Beebe, 1981], would involve follow-up of a cohort of individuals who filled out the long form of the 1980 census. The long form, which was completed by a 20% sample of households, contained entries for current occupation and industry. This cohort could be linked to the National Death Index [National Center for Health Statistics, 1981] to identify the fact of death, and cause of death could be obtained from the states. Confidentiality issues would need to be worked out in order for this proposal to be implemented.

## LIMITATIONS OF OCCUPATIONAL MORTALITY SURVEILLANCE

There are inherent deficiencies in the use of death certificates for occupational disease surveillance. Mortality surveillance is generally not suitable as an early

warning system for occupational diseases, as most fatal occupational diseases are chronic diseases and/or have long latency periods. Some diseases that are primarily occupational in origin, such as mesothelioma, do not have a unique International Classification of Diseases (ICD) code [World Health Organizaton, 1977] (the system used for coding cause of death on death certificates), and therefore cannot be reliably monitored. In addition, there are many serious occupational health problems that never result in death. Many occupational diseases that can result in death are not uniformly fatal. Analysis categories including only those who died from a disease, as opposed to all incident cases, result in misclassification. Random misclassification biases findings toward the null value. There are also potential biases due to possible differential survival rates for various diseases across occupations.

Sensitivity and misclassification problems are exacerbated by the use of a single underlying cause of death as the sole cause of death indicator, as all occupational mortality surveillance studies to date have done. Many death certificates, in fact, list more than one cause of death. Multiple cause of death coding can maximize the utilization of the cause of death information available on death certificates [Chamblee and Evans, 1982]. For example, in 1976, the disease rubric bronchitis, emphysema, and asthma was mentioned on death certificates 2.6 times more often than it was assigned as the underlying cause of death; the rubric nephritis and nephrosis was mentioned 3.1 times more often [Chamblee and Evans, 1982]. Both of these disease rubrics are of interest in occupational mortality surveillance. Public-use tapes with multiple cause of death coding for the period 1968–1983 by state are available from NCHS (although these tapes do not have occupation and industry codes). In addition, a number of states routinely do their own multiple cause of death coding.

Of couse, the use of multiple cause of death data does not address the problem of information which was omitted from the death certificate itself. This may be due to a lack of thoroughness on the part of the physician or coroner who completed the death certificate. Alternatively, it may be due to limited information available to the physician or coroner at the time that the death certificate was completed. For example, a disease may be masked by a sudden death, such as that caused by an accident, suicide, or acute myocardial infarction.

Another deficiency in the use of death certificates in their current form is that the usual occupation and industry are often poor substitutes for a complete work history. For a decedent who was employed in several different jobs over his or her lifetime, each for a significant amount of time, much information is lost by collecting usual occupation and industry only. Even short-term employment for a few months in a job with hazardous exposures can result in future disease, as has occurred with workers exposed to asbestos [Seidman et al, 1979]. Furthermore, death certificates contain no information on length of employment (with the exception of California) or occupational exposures.

Information on important potential confounding variables, such as cigarette smoking and alcohol consumption, is also not collected on death certificates. Social class is one potential confounding factor for which adjustment can be made in the analysis, using a social class classification scheme based upon occupation [Dubrow and Wegman, 1984a; Milham, 1985]. In principle, with considerable effort, adjustment can also be made for the effects of ethnicity. As described above, ethnicity can be inferred from the decedent's birthplace, the mother's maiden name, and the father's surname.

Consideration should be given to modifying death certificates to include brief entries on second major occupation and industry, length of employment, and cigarette smoking (which is usually the confounding variable of most concern).

In any data system in which hundreds of thousands of records are processed each year, the issue of data quality is especially critical. In occupational mortality surveillance, the main items of concern with respect to data quality are cause of death, usual occupation, and usual industry. There is need for improvement in the quality of these data items. The overall agreement of the underlying cause of death statement on death certificates with hospital diagnoses in the United States has been found to be approximately 65–70% [Gittelsohn and Senning, 1979; Percy et al, 1981], and the agreement with autopsy findings has been found to be somewhat lower [Engel et al, 1980; Kircher et al, 1985]. The reliability of the death certificate statement of underlying cause of death varies with respect to specific causes of death, and probably varies from state to state. Cause of death statements for malignant neoplasms, particularly of certain sites, appear to be more reliable than cause of death statements for most other causes. On the other hand, certain causes of death that are primarily occupational in origin, such as silicosis and asbestosis, are believed to be both greatly underdiagnosed [Abraham, 1980; Rosenstock, 1981], and underreported on death certificates [Hammond et al, 1979].

As discussed above, the agreement of the death certificate occupation and industry statements with other sources of information has been found to be in the 60–80% range. Agreement appears to be poorer for women and non-whites [Steenland and Beaumont, 1984]. The assignment of the usual occupation/industry of housewife to women often masks employment outside the home [Steenland and Beaumont, 1984; Swanson et al, 1984; Gute and Fulton, 1985; Schumacher, 1986].

A number of factors may contribute to inaccuracies in the death certificate occupation and industry statements. First, until recently, there were no published guidelines for the collection of this information by funeral directors, and training and query programs are still in their beginning stages. Second, an informant may not have adequate knowledge of the decedent's work history. The most recent occupation may be reported as the usual occupation [Buechley et al, 1956; Swanson et al, 1984]. Finally, next-of-kin may "promote" the decedent into a higher status occupation than was the reality [Buechley et al, 1956; Registrar General, 1978; Steenland and Beaumont, 1984].

Random errors in cause of death, occupation, and industry statements will dilute the results and decrease the power of the analysis. In addition, biases may result if some causes of death, occupations, or industries are selectively misassigned into others, or if the accuracy of the cause of death statement were social class (and therefore occupation) dependent. Such biases have been demonstrated to occur [Registrar General, 1978].

The limited accuracy of the death certificate cause of death and usual occupation and industry statements is not an inherent deficiency, as steps could be taken to improve data quality. This is particularly important for women and non-whites, given the need to study these groups and the relatively poor quality of current data. The assignment of the usual occupation/industry of housewife should be reserved for women who have never worked outside the home.

In spite of these various deficiencies, once usual occupation and industry entries are routinely coded, surveillance of occupational mortality can serve as a simple and

relatively inexpensive component of an occupational disease surveillance system and as a valuable epidemiologic resource.

## ACKNOWLEDGMENTS

We would like to thank Todd M. Frazier, William E. Crouse, and Lois L. Schuster of the NIOSH Surveillance Branch, and staff members of the NCHS, Bureau of the Census, NCI, and various state health departments for their contribution to the development of occupational mortality surveillance in the United States. Mr. Glenn Flinchum of NCHS kindly provided us with the information in Table I. We would also like to thank Corliss Straus and Betty Williams for help in preparing the manuscript.

## REFERENCES

Abraham JL (1980): Underdiagnosis of pulmonary asbestosis. N Engl J Med 302:464.

Beebe GW (1981): Record linkage and needed improvements in existing data resources. In Peto R, Schneiderman M (eds): "Banbury Report 9: Quantification of Occupational Cancer." Cold Spring Harbor, NY: Cold Spring Harbor Laboratory, pp 661–673.

Brocker JE, Levy MI, Kan SH (1985): "Utah's Occupational Health Surveillance System 1980–1982." Salt Lake City, UT: Utah Department of Health.

Buechley R, Dunn JE, Linden G, Breslow L (1956): Death certificate statement of occupation: its usefulness in comparing mortalities. Public Health Rep 71:1105–1111.

Burkart JA (1983): Musculoskeletal diseases in lumber and wood products workers as identified through hospital records surveillance. Am J Ind Med 4:725–732.

Burkart JA, Egleston CF, Voss RJ (1978): "The Rural Health Study: A Comparison of Hospital Experience Between Farmers and Nonfarmers in a Rural Area of Minnesota." Cincinnati, OH: National Institute for Occupational Safety and Health (DHEW [NIOSH] Publication No. 78-184).

Burkart JA, Turner ER, Nicholson PR (1981): "Using Hospital Records for Health Surveillance of Workers in the Lumber and Wood Products Industries." Salt Lake City, UT: University of Utah Research Institute (NIOSH Contract No. 210-78-0066).

Burmeister LF (1981): Cancer mortality in Iowa farmers, 1971–78. J Natl Cancer Inst 66:461–464.

Byars DM (1983): "Guidelines for Reporting Occupation and Industry on Death Certificates." Hyattsville, MD: National Center for Health Statistics.

Chamblee RF, Evans MC (1982): New dimensions in cause of death statistics. Am J Public Health 72:1265–1270.

Crouse W, Schuster L, Rosenberg H, Kametani D, Sestito J (1983): Using the Census Bureau's occupation and industry coding system for coding death certificates. In "Statistics of Income and Related Administrative Record Research: 1983, Selected Papers Given at the 1983 Annual Meeting of the American Statistical Association in Toronto, Canada, August 15–18, 1983." Washington, DC: Internal Revenue Service, pp 53–57.

Decouflé P, Stanislawczyk K, Houten L, Bross IDJ, Viadana E (1977): "A Retrospective Survey of Cancer in Relation to Occupation." Cincinnati, OH: National Institute for Occupational Safety and Health (DHEW [NIOSH] Publication No. 77-178).

Decouflé P, Thomas TL, Pickle LW (1980): Comparison of the proportionate mortality ratio and standardized mortality ratio risk measures. Am J Epidemiol 111:263–269.

Delzell E, Grufferman S (1983): Cancer and other causes of death among female textile workers, 1976–78. J Natl Cancer Inst 71:735–740.

Delzell E, Grufferman S (1985): Mortality among white and nonwhite farmers in North Carolina, 1976–1978. Am J Epidemiol 121:391–402.

Dubrow R (1986): Malignant melanoma in the printing industry. Am J Ind Med 10:119–126.

Dubrow R, Burnett CA (1985): "Research Leads from SCANS Data." Cincinnati, OH: National Institute for Occupational Safety and Health.

Dubrow R, Wegman DH (1983): Setting priorities for occupational cancer research and control: Synthesis of the results of occupational disease surveillance studies. J Natl Cancer Inst 71:1123–1142.

Dubrow R, Wegman DH (1984a): "Occupational Characteristics of Cancer Victims in Massachusetts 1971–1973." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 84-109).

Dubrow R, Wegman DH (1984b): Cancer and occupation in Massachusetts: A death certificate study. Am J Ind Med 6:207–230.

Dubrow R, Gute DM (1987): Cause-specific mortality among Rhode Island jewelry workers. Am J Indust Med 11 (submitted for publication).

Engel LW, Strauchen JA, Chiazze L, Heid M (1980): Accuracy of death certification in an autopsied population with specific attention to malignant neoplasms and vascular diseases. Am J Epidemiol 111:99–112.

Fischbach T, Crouse W, Sestito J, Green J (1986a): "Industry and Disabling Conditions of Disabled Workers 1975–1976: Analysis of Social Security Disability Benefit Allowances to Workers During 1975–1976." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 86-105).

Fischbach TJ, Dacey EW, Sestito JP, Green JH (1986b): "Occupational Characteristics of Disabled Workers 1975–1976: Analysis of Social Security Disability Benefit Allowances to Workers During 1975–1976." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 86-106).

Frazier TM, Coleman PJ (1983): "Job Injuries Among Loggers." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 83-104).

Garabrant DH, Wegman DH (1984): Cancer mortality among shoe and leather workers in Massachusetts. Am J Ind Med 5:303–314.

Gittelsohn A, Senning J (1979): Studies on the reliability of vital and health records: I. Comparison of cause of death and hospital record diagnoses. Am J Public Heatlh 69:680–689.

Guralnick L (1963): "Mortality by Occupation/Industry and Cause of Death Among Men 20 to 64 Years of Age: United States, 1950." Washington, DC: Public Health Service (Vital Statistics—Special Reports 53, No. 3, 4).

Gute DM (1981): "The Association of Occupation and Industry with Mortality in Rhode Island (1968–1972)." Providence, RI: Rhode Island Department of Health (Technical Report No. 23, Health Planning and Development).

Gute DM, Fulton JP (1985): Agreement of occupation and industry data on Rhode Island death certificates with two alternative sources of information. Public Health Rep 100:65–72.

Hammond EC, Selikoff IJ, Seidman H (1979): Asbestos exposure, cigarette smoking and death rates. Ann NY Acad Sci 330:473–490.

Helgerson SD, Milham S (1985): Farm workers electrocuted when irrigation pipes contact powerlines. Public Health Rep 100:325–328.

Howe GR, Lindsay JP (1983): A follow-up study of a ten-percent sample of the Canadian labor force. I. Cancer mortality in males, 1965–73. J Natl Cancer Inst 70:37–44.

Kaminski R, Brockert J, Sestito J, Frazier T (1981): Occupational information on death certificates: A survey of state practices. Am J Public Health 71:525–526.

Kaminski R, Spirtas R (1980): "Industrial Characteristics of Persons Reporting Morbidity During the Health Interview Surveys Conducted in 1969–1974: An Exploratory Review." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 80-123).

Kaplan DL, Parkhurst E, Whelpton PK (1961): "The Comparability of Reports on Occupation from Vital Records and the 1950 Census." Washington, DC: Public Health Service (Vital Statistics—Special Reports 53, No. 1).

Kelley BC, Gute DM (1986): "Surveillance Cooperative Agreement Between NIOSH and States (SCANS) Program, Rhode Island 1980–1982." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 86-107).

Kennedy J, Fischbach TJ, Green JH, Leihy RE (1980): "Occupational Characteristics of Disabled Workers: Analysis of Social Security Disability Benefit Awards to Workers During 1969–1972." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 80-145).

Kircher T, Nelson J, Burdo H (1985): The autopsy as a measure of accuracy of the death certificate. N Engl J Med 313:1263–1269.

Kupper LL, McMichael AJ, Symons MJ, Most BM (1978): On the utility of proportional mortality analysis. J Chron Dis 31:15–22.

Lassiter DV, Schulman J, Siquiera SL, Stubbs HA, Whorton MD, Austin D (1980): "The Feasibility of Using a Population-Based Tumor Registry to Identify Occupational/Industrial Cohorts at Elevated Risks of Developing Cancer." Cincinnati, OH: National Institute for Occupational Safety and Health (NIOSH Contract No. 210-78-0072).

MacCubbin PA, Herzfeld PM, Therriault GD (1986): "Mortality in New York State, 1980–1982, A Report by Occupation and Industry." Albany, NY: New York State Department of Health.

Milham S (1976): "Occupational Mortality in Washington State." Cincinnati, OH: National Institute for Occupational Safety and Health (HEW [NIOSH] Publication No. 76-175).

Milham S (1979): Mortality in aluminum reduction plant workers. J Occup Med 21:475–480.

Milham S (1983): "Occupational Mortality in Washington State 1950–1979." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 83-116).

Milham S (1985): Improving occupational standardized proportionate mortality ratio analysis by social class stratification. Am J Epidemiol 121:472–475.

Milham S, Demers RY (1984): Mortality among pulp and paper workers. J Occup Med 26:844–846.

National Center for Health Statistics (1977): "Statistics Needed for Determining the Effects of the Environment on Health—Report of the Technical Consultant Panel to the United States National Committee on Vital and Health Statistics." Hyattsville, MD: National Center for Health Statistics (DHEW Publication No. [HRA] 77-1457).

National Center for Health Statistics (1981): "User's Manual—The National Death Index." Hyattsville, MD: National Center for Health Statistics (DHHS Publication No. [PHS] 81-1148).

National Center for Health Statistics (1985): "Vital Statistics of the United States, 1980, Volume II—Mortality, Part A." Hyattsville, MD: National Center for Health Statistics (DHHS Publication No. [PHS] 85-1101).

Office of Management and Budget (1972): "Standard Industrial Classification Manual." Washington, DC: US Government Printing Office.

Osborne R, Fischbach T (1985): "Causes of Disability in Employees of the Mining Industry: Analysis of Social Security Disability Benefit Awards and Allowances to Workers 1969–1973, 1975–1976." Cincinnati, OH: National Institute for Occupational Safety and Health (DHHS [NIOSH] Publication No. 85-105).

Pennsylvania Department of Health (1985): "Mortality Experience of Pennsylvania Workers 1983." Harrisburg, PA: Pennsylvania State Health Data Center.

Percy C, Stanek E, Gloeckler L (1981): Accuracy of cancer death certificates and its effect on cancer mortality statistics. Am J Public Health 71:242–250.

Petersen GR, Milham S (1980): "Occupational Mortality in the State of California 1959–1961." Cincinnati, OH: National Institute for Occupational Safety and Health (DHEW [NIOSH] Publication No. 80-104).

Registrar General (1978): "Occupational Mortality, Decennial Supplement for England and Wales, 1970–1972." London: Her Majesty's Stationery Office.

Rosenberg HM, Burnham D, Spirtas R, Valdisera V (1984): Occupation and industry information from the death certificate: Assessment of the completeness of reporting. In Kilss B, Alvey W (eds): "Statistical Uses of Administrative Records: Recent Research and Present Prospects, Volume 2." Washington, DC: Internal Revenue Service, pp 419–425.

Rosenstock L (1981): Occupational medicine: too long neglected. Ann Intern Med 95:774–776.

Rutstein DD, Mullan RJ, Frazier TM, Halperin WE, Melius JM, Sestito JP (1983): Sentinel Health Events (Occupational): A basis for physician recognition and public health surveillance. Am J Public Health 73:1054–1062.

Schumacher MC (1986): Comparison of occupation and industry information from death certificates and interviews. Am J Public Health 76:635–637.

Seidman H, Selikoff IJ, Hammond EC (1979): Short-term asbestos work exposure and long-term observation. Ann NY Acad Sci 330:61–90.

Seligman PJ, Halperin WE, Mullan RJ, Frazier TM (1986): Occupational lead poisoning in Ohio; Surveillance using workers' compensation data. Am J Public Health 76:1299–1302.

Shilling S, Lalich NR (1984): Maternal occupation and industry and the pregnancy outcome of U.S. married women, 1980. Public Health Rep 99:152–161.

Sparks PJ, Wegman DH (1980): Cause of death among jewelry workers. J Occup Med 22:733–736.

Steenland K, Beaumont J (1984): The accuracy of occupation and industry data on death certificates. J Occup Med 26:288–296.

Stubbs HA, Harris J, Spear RC (1984): A proportionate mortality analysis of California agricultural workers, 1978–1979. Am J Indus Med 6:305–320.

Swanson GM, Schwartz AG, Burrows RW (1984): An assessment of occupation and industry data from death certificates and hospital medical records for population-based cancer surveillance. Am J Public Health 74:464–467.

US Bureau of the Census (1982): "1980 Census of Population Alphabetical Index of Industries and Occupations." Washington, DC: US Bureau of the Census.

US Bureau of the Census (1984): "Industry and Occupation Coding for Death Certificates. Instruction Manual, Part 19." Hyattsville, MD: National Center for Health Statistics.

US Department of Commerce (1980): "Standard Occupational Classification Manual." Washington, DC: US Department of Commerce.

Walrath J, Rogot E, Murray J, Blair A (1985): "Mortality Patterns Among U.S. Veterans by Occupation/ Industry and Smoking Status." Bethesda, MD: National Institutes of Health (NIH Publication Nos. 85-2747, 85-2756).

Wegman DH, Peters JM (1978): Oat cell lung cancer in selected occupations—a case-control study. J Occup Med 20:793–796.

Whorton MD, Schulman J, Larson SR, Stubbs HA, Austin D (1983): Feasibility of identifying high-risk occupations through tumor registries. J Occup Med 25:657–660.

World Health Organization (1968): The surveillance of communicable diseases. WHO Chronicle 22:439–453.

World Health Organization (1977): "International Classification of Disease, 1975 Revision." Geneva: World Health Organization.