# Asbestosis Mortality Surveillance in the United States, 1970–2004

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To describe the demographic, geographic, and occupational distribution of asbestosis mortality in the United States during 1970–2004, we identified a total of 25,413 asbestosis deaths. We calculated national, state, and county death rates, age-adjusted to the 2000 U.S. standard population. We also calculated industry- and occupation-specific proportionate mortality ratios (PMRs), adjusted for age, sex, and race, and corresponding confidence intervals (CIs) using available data. The overall U.S. age-adjusted asbestosis death rate was 4.1 per million population per year; the rate for males (10.4) was nearly 35-fold higher than that for females (0.3). It increased significantly from 0.6 to 6.9 per million population from 1970 to 2000 ($p<0.001$), and then declined to 6.3 in 2004 ($p=0.014$). High asbestosis death rates occurred predominantly, though not exclusively, in coastal areas. Industries with highest PMRs included *ship and boat building and repairing* (18.5; 95% CI 16.3–20.9) and *miscellaneous nonmetallic mineral and stone products* (15.9; 95% CI 13.0–19.5). Occupations with highest PMRs included *insulation workers* (109.2; 95% CI 93.8–127.2) and *boilermakers* (21.3; 95% CI 17.0–26.6).
*Key words*: asbestosis, mortality, occupation, industry

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Asbestosis is a diffuse interstitial fibrosis of the lungs due to inhalation and retention of asbestos fibers. The term "asbestos" generally refers to six naturally occurring fibrous silicate minerals classified by their physical and chemical structure into two groups: 1) serpentine, which include chrysotile (white asbestos); and 2) amphiboles, which include amosite (brown asbestos), crocidolite (blue asbestos), anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. The most commonly encountered form of asbestos is chrysotile (approximately 95% of the asbestos used in the United States), followed by amosite and crocidolite. All forms of asbestos can cause asbestosis.

Generally, there is a latency period of about 15 to 45 years from initial exposure to development of asbestosis. However, asbestosis latency can be shorter than 15 years when intensity of asbestos exposure is exceedingly high. Progression of asbestosis depends on asbestos exposure level and duration of exposure.

In addition to asbestosis, exposure to asbestos can cause malignant mesothelioma, lung cancer, nonmalignant pleural abnormalities including plaques, and other conditions.

Workers employed in asbestos mining and milling are at potential risk of exposure to asbestos, as are workers involved with manufacture, use, repair, removal, or demolition of asbestos-containing materials and products including, for example, asbestos-containing building materials, insulation, friction products, and textiles. Examples of specific trades considered at high risk for asbestos exposure include insulators, sheet metal workers, carpenters, welders and cutters, plumbers and pipefitters, steamfitters, boilermakers, plasterboard workers, and numerous shipyard trades such as electricians and shipscalers.[·] The Occupational Safety and Health Administration (OSHA) has estimated that annually 1.3 million construction and general industry workers in the United States (U.S.) are potentially exposed to asbestos, most prominently during manipulation of asbestos while conducting renovation or demolition.[12] Asbestos may also be found in dust from unpaved roads or driveways surfaced with ultramafic or serpentine rock material.[13] While the use of asbestos has been banned in some countries, including the entire European Union,[14] its use has not been entirely banned in the U.S. Because of past asbestos exposures, continuing use of asbestos, and maintenance and demolition involving asbestos-containing materials, U.S. workers will continue to be at risk for asbestosis for years to come.

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**TABLE 1 Number and Percent Distributions of Asbestosis Deaths and Asbestosis Death Rates (per Million Population per Year) by Demographic Characteristics, U.S. Residents Aged ≥15 Years, 1970–2004**

| | Deaths | | Death Rate |
|---|---|---|---|
| Demographics | No. | % | Age-specific |
| Age group (years) | | | |
| 15–24 | 1 | 0.0 | 0.0 |
| 25–34 | 4 | 0.0 | 0.0 |
| 35–44 | 64 | 0.3 | 0.1 |
| 45–54 | 609 | 2.4 | 0.8 |
| 55–64 | 3,310 | 13.0 | 4.4 |
| ≥65 | 21,425 | 84.3 | 20.7 |
| | | | Age-adjusted |
| Sex | | | |
| Male | 24,463 | 96.3 | 10.4 |
| Female | 950 | 3.7 | 0.3 |
| Race | | | |
| White | 23,764 | 93.5 | 4.3 |
| Black | 1,507 | 5.9 | 3.0 |
| Other | 142 | 0.6 | 1.4 |
| Total | 25,413 | 100.0 | 4.1 |

In this article, we describe the demographic characteristics of asbestosis decedents and the geographic distributions and temporal trends of asbestosis deaths in the U.S. In addition, we present proportionate mortality ratios (PMRs) for asbestosis by industry and occupation.

## MATERIALS AND METHODS

Information on deaths from occupationally-related respiratory disease and conditions is compiled by the National Institute for Occupational Safety and Health in the National Occupational Respiratory Mortality System (NORMS).[15] This database uses National Center for Health Statistics (NCHS) multiple cause-of-death data obtained annually from all individual death certificates in the U.S. For a subset of 26 states for some years in the 1985–1999 period, information on decedents' usual industry and occupation that complies with NCHS-established quality criteria is available in the NCHS multiple cause-of-death data.[15]

For this analysis, we defined asbestosis deaths as those for which asbestosis was entered on the death certificate. We identified such deaths using International Classification of Disease (ICD)-8 code 515.2 for years 1970–1978, ICD-9 code 501 for years 1979–1998, and ICD-10 code J61 for years 1999–2004.[16–18] We considered all U.S. resident deaths occurring at ages 15 years and older; the age restriction is due to the occupational nature of asbestosis. For those analyses based on decedents' occupation or industry, we further limited consideration to the subset of states and years for which quality industry and occupation data were available.

We age-adjusted the death rates (deaths per million per year) to the 2000 U.S. standard population and mapped age-adjusted death rates at the county level using geographic information system software (MapInfo Professional Software® 7.5, MapInfo Corp., Troy, NY). We used a simple linear regression model for time trend analysis of rates. We calculated PMRs as the observed number of asbestosis deaths in a specified industry or occupation (coded to 3-digits using the Bureau of Census Industry Code [CIC] and Occupation Code [COC], respectively[19]) divided by the expected number of asbestosis deaths. We calculated the expected number of asbestosis deaths using the total number of deaths in the specified industry or occupation multiplied by a proportion defined as the number of asbestosis deaths in all industries or occupations divided by the total number of deaths in all industries or occupations. We adjusted PMRs by industry and occupation for age, sex, and race, and 95% confidence intervals were calculated by Poisson analysis.[20] For this report, we calculated PMRs only for industries and occupations with five or more asbestosis deaths in the 1985–1999 period. We used SAS® 9.1 software (SAS Institute, Cary, NC) for data analysis.

## RESULTS

The demographic characteristics of asbestosis decedents and age-adjusted death rates by sex and race are shown in Table 1, as are age-specific death rates per million population per year. For 1970–2004, a total of 25,413 asbestosis deaths were identified; 24,463 (96.3%) were males and 23,764 (93.5%) were whites. The overall age-adjusted asbestosis death rate was 4.1 per million population per year; males (10.4) had a nearly 35-fold higher rate than females (0.3). Age-specific death rates ranged from 0.0 per million per year in both of the youngest age groups (15–24 years and 25–34 years) to 20.7 in the oldest age group (65 years and older).

The number of asbestosis deaths increased from 89 in 1970 to 1,493 in 2000 and then declined to 1,470 in 2004. The annual age-adjusted death rate showed a similar temporal pattern. It increased from 0.6 per million population per year in 1970 to 6.9 in 2000 ($r^2$=0.97, slope=0.219, $p$<0.0001), and then declined to 6.3 in 2004 ($r^2$=0.90, slope=–0.114, $p$=0.014) (Figure 1).

For the 1970–2004 period, asbestosis deaths were most frequent in California (n=2,588), New Jersey (n=2,208), and Pennsylvania (n=2,168). The 25 states with highest age-adjusted death rates are shown in Table 2. Delaware had the highest asbestosis death rate (14.3 per million per year), more than three-fold higher than the national rate, though six other states (Washington, New Jersey, Alaska, West Virginia, Maine, and Mississippi) each had asbestosis death rates more than two-fold higher than the overall U.S. rate. Most of the states with the highest asbestosis death rates are coastal states or other states with major seaports.

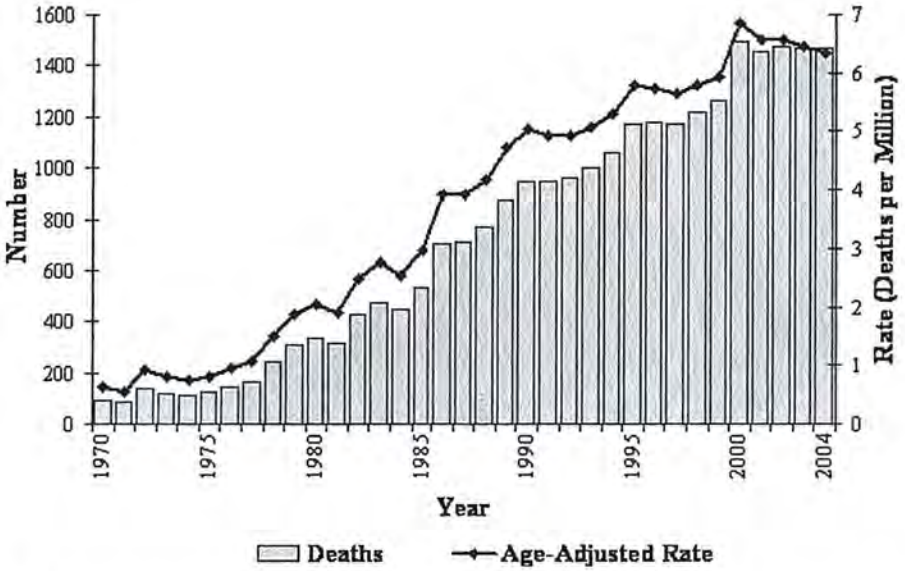


*Figure 1—Number of asbestosis deaths and age-adjusted death rates (per million) by year, U.S. residents aged ≥15 years, 1970–2004.*

Geographic distribution of asbestosis death rates by county is presented in Figure 2. Lincoln County, Montana, had the highest asbestosis death rate (164.1 per million per year), 40-fold higher than the overall U.S. rate, followed by Poquoson City, Virginia (132.5); George County, Mississippi (111.7); Orange County, Texas (102.5); and Somerset County, New Jersey (101.2) (Table 3).

The 10 industries and 10 occupations with the highest significantly elevated PMRs for asbestosis are shown in Table 4. By industry, *ship and boat building and repairing* had the highest PMR of 18.5 (95% CI 16.3–20.9), followed by *miscellaneous nonmetallic mineral and stone products* (PMR=15.9; 95% CI 13.0–19.5). In addition to the industries listed in the table, eight other industries (including *water transportation, electric light and power, drugs, construction, glass and glass products, tires and inner tubes,* and *railroads*) had significantly elevated PMRs. By occupation, *insulation workers* had the highest PMR (109.2.; 95% CI 93.8–127.2), followed by *boilermakers* (PMR=21.3; 95% CI 17.0–26.6). In addition to the occupations listed in the table, 24 other occupations (including *electricians, sailors and deckhands, millwrights, welders and cutters, brickmasons and stonemasons, industrial machinery repairers,* and *carpenters*) had significantly elevated PMRs.

## DISCUSSION

This report summarizes surveillance information on 25,413 asbestosis deaths in the U.S. over 35 years from 1970 through 2004. The annual number of asbestosis deaths increased nearly 17-fold from 1970 to 2000 and has declined slightly after 2000. Asbestosis decedents have been overwhelmingly white males. About 15% of all asbestosis decedents were younger than 65 years old. High death rates were observed mainly in coastal areas. Among industries, *ship and boat building and repairing* had

**TABLE 2 Numbers of Asbestosis Deaths and Asbestosis Death Rates for the 25 States with Highest Age-adjusted Death Rates (per Million per Year), U.S. Residents Aged ≥15 Years, 1970–2004**

| State | No. of Deaths | Age-adjusted Death Rate |
|---|---|---|
| Delaware | 215 | 14.3 |
| Washington | 1,252 | 11.7 |
| New Jersey | 2,208 | 10.8 |
| Alaska | 36 | 10.5 |
| West Virginia | 494 | 9.2 |
| Maine | 274 | 8.4 |
| Mississippi | 541 | 8.3 |
| Maryland | 797 | 7.9 |
| Virginia | 991 | 7.7 |
| Oregon | 549 | 7.4 |
| Alabama | 689 | 6.5 |
| Pennsylvania | 2,168 | 6.0 |
| Montana | 123 | 6.0 |
| Massachusetts | 965 | 5.8 |
| South Carolina | 404 | 5.4 |
| Texas | 1,808 | 5.4 |
| New Hampshire | 129 | 5.1 |
| Louisiana | 470 | 4.9 |
| Idaho | 108 | 4.7 |
| Wyoming | 39 | 4.4 |
| Rhode Island | 125 | 4.4 |
| California | 2,588 | 4.3 |
| Nevada | 89 | 4.2 |
| North Carolina | 650 | 4.1 |
| Connecticut | 331 | 3.7 |
| All states | 25,413 | 4.1 |

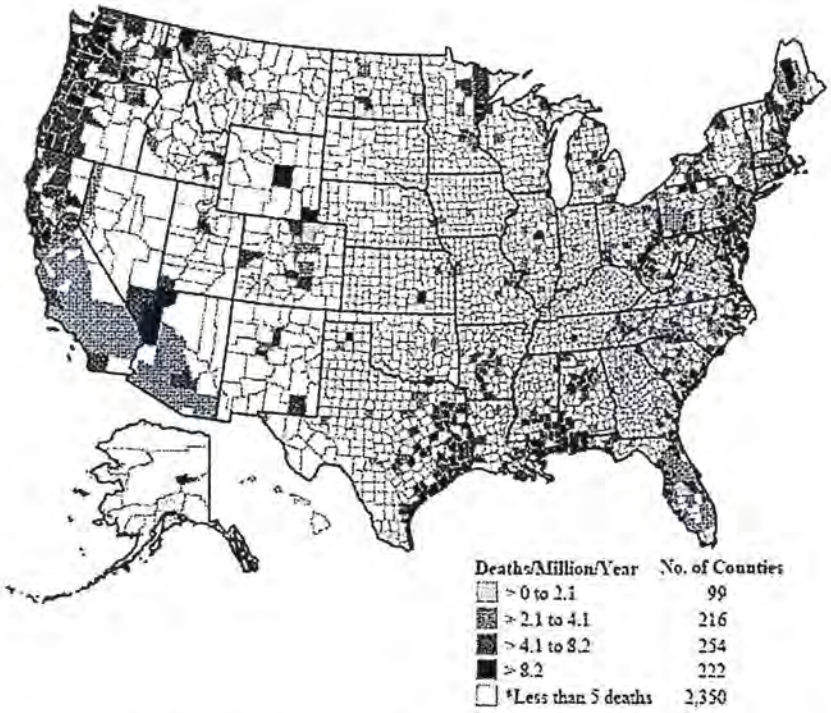


*Figure 2—Age-adjusted asbestosis death rates (per million per year) by county, United States, 1970–2004.*

Note: The national age-adjusted death rate for 1970–2004 was 4.1 per million.
*Rates were not calculated for those counties with less than 5 deaths.

the highest PMR for asbestosis. Among occupations, *insulations workers* had the highest PMR for asbestosis.

The slight decline in U.S. asbestosis mortality from 2000 through 2004 is probably attributable to a combination of factors, and might indicate that asbestosis mortality has peaked in the U.S. Major factors that could account for a downward trend in asbestos mortality are declining use of asbestos and improved control of asbestos exposures. Because asbestosis mortality typically manifests several decades after initial occupational exposure to asbestos, the asbestosis deaths we observed reflect exposures that occurred decades earlier. Asbestos use in the U.S. increased from approximately 1,000 metric tons in the early 1900s to a peak of 803,000 tons in 1973. Increased awareness of the health consequences of asbestos exposure led to voluntary and regulatory actions that resulted in subsequent decline in asbestos use to less than 4,000 metric tons in 2004.[21] Patterns of asbestos use in many other developed countries have been reported to be similar to that for the U.S., with peak usage in the 1970s.[21]

Asbestos has been used in many products and applications (e.g., brake pads and linings, roofing materials, gaskets, heat and acoustic insulation, fireproofing, flooring material).[22] The U.S. Environmental Protection Agency (EPA) first promulgated an asbestos standard in 1973, which included a ban on the use of spray-applied material containing more than 1% asbestos for insulating or fireproofing buildings.[23] Subsequent actions by EPA and the Consumer Products Safety Commission have resulted in several additional selective banned uses of asbestos in the U.S., including: 1) new uses of asbestos; 2) corrugated paper; 3) rollboard; 4) commercial paper; 5) specialty paper; and 6) flooring felt.[23] An "Asbestos Ban and Phaseout Rule" was promulgated by EPA in 1989, but many aspects of this EPA standard were set aside by court action in 1991.[23] No longer subject to the 1989 ban are the following asbestos-containing product categories: asbestos-cement corrugated and flat sheet, shingle, millboard, and pipe; asbestos clothing; pipeline wrap; gaskets; roofing felt and roof coatings; non-roofing coatings; vinyl-asbestos floor tile; automatic transmission components, friction materials, clutch facings, and brake pads, linings, and blocks.[23] Efforts to ban all uses of asbestos in the U.S. continue.[24] Since 2005, asbestos use has been nearly totally banned in all 25 member countries of the European Union; asbestos-containing diaphragms can be manufactured until 2010.[14]

EPA standards intended to control emissions of asbestos into the environment have been complemented by OSHA standards intended to reduce occupational asbestos exposures. OSHA established a permissible exposure limit (PEL) for asbestos in 1971. This initial PEL of 12 fibers per cubic centimeter (f/cc) has subsequently been reduced to 5 f/cc in 1972, 2 f/cc in

**TABLE 3 Numbers of Asbestosis Deaths and Asbestosis Death Rates for the 30 Counties and County Equivalents* with Highest Age-adjusted Death Rates (per Million per Year), U.S. Residents Aged ≥15 Years, 1970–2004**

| County (or County Equivalent) | State | No. of Deaths | Age-adjusted |
|---|---|---|---|
| Lincoln County | Montana | 64 | 164.1 |
| Poquoson City | Virginia | 17 | 132.5 |
| George County | Mississippi | 39 | 111.7 |
| Orange County | Texas | 156 | 102.5 |
| Somerset County | New Jersey | 519 | 101.2 |
| Jackson County | Mississippi | 163 | 82.0 |
| Kitsap County | Washington | 222 | 60.9 |
| Sagadahoc County | Maine | 44 | 57.8 |
| York County | Virginia | 28 | 56.5 |
| Newport News City | Virginia | 151 | 55.1 |
| Greene County | Mississippi | 13 | 51.6 |
| Hampton City | Virginia | 114 | 50.8 |
| Jefferson County | Texas | 254 | 39.6 |
| Jasper County | Texas | 35 | 38.6 |
| Gloucester County | New Jersey | 165 | 37.0 |
| Putnam County | West Virginia | 31 | 36.1 |
| Berkeley County | South Carolina | 46 | 35.6 |
| Chesapeake City | Virginia | 81 | 35.5 |
| Isle of Wight County | Virginia | 19 | 35.0 |
| Suffolk City | Virginia | 44 | 34.8 |
| Newton County | Texas | 13 | 33.7 |
| Camden County | New Jersey | 402 | 33.4 |
| Chambers County | Texas | 11 | 30.2 |
| Charleston County | South Carolina | 157 | 29.3 |
| Portsmouth City | Virginia | 84 | 29.2 |
| Washington County | Alabama | 12 | 28.6 |
| Solano County | California | 150 | 28.6 |
| Mobile County | Alabama | 245 | 27.4 |
| Hardin County | Texas | 26 | 27.4 |
| Benton County | Washington | 56 | 25.8 |

* In Virginia, some cities incorporate the same legal or geopolitical status as counties.

1976, 0.2 f/cc in 1986, and 0.1 f/cc in 1994.[25] The OSHA standard requires employers to use engineering controls, specific work practices, exposure monitoring, housekeeping practices, medical surveillance, work training and hazard education, and use of personal protective equipment to control exposures.[26] Inspection data for 1979–1999 show declines in asbestos exposure and percent of samples exceeding designated occupational exposure limits in construction, manufacturing, mining, and other industries.[27]

Reduced use and lower asbestos exposure levels may have contributed to recent reductions in asbestosis mortality observed since 2000. However, because of the latency of asbestosis, the full impact of these reductions in asbestos use and exposures on disease occurrence is still decades in the future. Several studies have attempted to project the future trends of asbestos-related diseases incidence and mortality.[4,28–37] Most of these studies were restricted to asbestos-related cancers. However, Nicholson et al., in a 1982 study on U.S. asbestos-related mortality, hypothesized that asbestosis deaths would double during the 1980s and 1990s (to approximately 400 deaths annually), and decline thereafter.[4] Although the authors considered past exposure to asbestos and estimated number of exposed workers, they could not take into account other factors that occurred after their study was completed, such as increasingly restrictive regulations for asbestos exposure and use (see above), improved diagnostic methods, and changing medicolegal considerations.

Over the past several decades, new and improved diagnostic technologies, such as conventional and high-resolution computed tomography (HRCT), have been increasingly utilized to diagnose asbestos-related diseases.[38–40] Because HRCT has higher specificity than conventional chest radiography for diagnosing asbestosis,[39,40] many false-positive diagnoses based on conventional chest radiography alone can be eliminated.[41] However, because HRCT has higher sensitivity than conventional chest radiography for diagnosing asbestosis,[39,40] more true-positive diagnoses can be identified by HRCT than by conventional chest radiography alone.[41] Because no studies have examined the net effect of these changes, the impact of increasing utilization of HRCT on the temporal trend in asbestosis deaths remains unknown.

**TABLE 4 Asbestosis Proportionate Mortality Ratios (PMRs) and 95% Confidence Intervals (CIs) for the Ten Industries and Ten Occupations with the Highest Significantly Elevated PMRs, Selected States and Years,* U.S. Residents Aged ≥15 Years, 1985–1999**

| Bureau of Census Classification (Code) | No. of Deaths | PMR | 95% CI |
|---|---|---|---|
| Industry | | | |
| Ship and boat building and repairing (360) | 254 | 18.5 | 16.3–20.9 |
| Misc. nonmetallic mineral and stone products (262) | 98 | 15.9 | 13.0–19.5 |
| Lumber and construction materials (502) | 23 | 6.3 | 4.0–9.4 |
| Industrial and miscellaneous chemicals (192) | 148 | 4.9 | 4.1–5.7 |
| Other rubber prod., plastics footwear, belting (211) | 42 | 3.6 | 2.6–4.8 |
| Petroleum refining (200) | 40 | 3.0 | 2.1–4.1 |
| Electric and gas, and other combinations (462) | 16 | 2.9 | 1.6–4.7 |
| Fabricated structural metal products (282) | 44 | 2.7 | 2.0–3.6 |
| Plastics, synthetics, and resins (180) | 15 | 2.7 | 1.5–4.4 |
| Primary aluminum industries (272) | 21 | 2.6 | 1.6–4.0 |
| Industry not reported (990) | 136 | | |
| All other industries | 2,808 | | |
| Total | 3,645 | | |
| Occupation | | | |
| Insulation workers (593) | 172 | 109.2 | 93.8–127.2 |
| Boilermakers (643) | 80 | 21.3 | 17.0–26.6 |
| Lay-out workers (646) | 13 | 11.5 | 6.1–19.6 |
| Plumbers, pipefitters, and steamfitters (585) | 317 | 9.8 | 8.8–11.0 |
| Marine and naval architects (058) | 8 | 7.3 | 3.1–14.3 |
| Sheet metal workers (653) | 71 | 6.5 | 5.1–8.3 |
| Plasterers (584) | 12 | 6.5 | 3.3–11.3 |
| Chemical technicians (224) | 10 | 5.2 | 2.5–9.5 |
| Heating, air cond., and refrigeration mechanics (534) | 21 | 4.6 | 2.8–7.0 |
| Supervisors: plumbers, pipefitters, steamfitters (557) | 7 | 4.6 | 1.8–9.4 |
| Occupation not reported (999) | 132 | | |
| All other occupations | 2,802 | | |
| Total | 3,645 | | |

*Alaska, Colorado, Georgia, Hawaii, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin. (For some of these states, data were not available for all years in the 1985–1999 period.[15])

There are some studies on the potential for misclassification of cause of death and validation of the causes of death on death certificates.[42,43] Goraya et al. validated the death certificate diagnosis of out-of-hospital coronary heart disease (CHD) and sudden cardiac death. The authors reported a high sensitivity (91%) and specificity (86%) of the death certificate definition and concluded that death certificate diagnoses result in about 5% underestimation of the true CHD rates.[42] Rosenman et al. reported that of 110 deaths with silicosis mentioned on the death certificate, approximately 77% had a confirmed diagnosis of silicosis.[43]

In the U.S., there have been over 700,000 asbestos claimants through 2002 and at least 73 asbestos-related bankruptcies of asbestos defendant corporations through mid-2004.[44] These claims for compensation have risen dramatically over the past several decades. In the Manville Trust, claims rose about 8-fold in number from 1990 to 2003.[45] Of the approximately 92,000 claims in 2003, about 87% were for non-malignant diseases, including asbestosis. From 2004–2006 the number of claims declined markedly, to about 10,000 claims for non-malignant diseases in 2004.This rise and fall has been said to be heavily influenced by artifactual causes, with the rise ascribed to efforts to recruit claimants through mass screening conducted by law firms, and the drop ascribed to a recent legal decision in silicosis litigation that questioned the validity of many diagnoses from mass screening programs.[45] The potential implication of this rise and fall in asbestos claimants for the observed temporal trend in asbestosis deaths is unclear. Various scenarios are possible. If asbestosis claims and deaths are uninfluenced by medicolegal considerations, the observed asbestosis mortality would be expected to more or less reflect a valid—though delayed—pattern of the true temporal trend in asbestosis. On the other hand, if asbestos litigation raises awareness of asbestosis-related diseases, the validity of the temporal pattern could be impacted. Increased awareness could lead to more frequent accurate diagnosis of asbestosis and associated subsequent accurate reporting of asbestosis as an underlying or contributing cause of death on death certificates. The net effect of these and other hypothetical considerations is obviously complex and has not been investigated.

The observed geographic distribution of U.S. asbestosis mortality favors coastal states, reflecting the highest industry-specific PMR for asbestosis that was associated with the *ship and boat building and repairing* industry. Lincoln County, Montana, with the highest county-specific asbestosis mortality rate in the U.S., is a clear exception to the general coastal pattern. This county's high asbestosis mortality is explained by exposures associated with asbestos-contaminated vermiculite formerly mined there.[46] Widespread use of asbestos as ship insulation and high asbestos exposures associated with applying asbestos insulation in the relatively confined spaces within ships have long been known to represent high risk for asbestosis.[4,5,47] Other industries associated with significantly elevated PMRs in our analyses include those involving manufacture of asbestos products (e.g., *miscellaneous nonmetallic mineral and stone products*) or asbestos-containing products (e.g., *lumber and construction materials*) or industries involving high-temperature processes requiring asbestos insulation and asbestos gaskets (e.g., *petroleum refining*).

Among occupations, the highest PMR for asbestosis was associated with *insulation workers* (PMR=109), long-known to be at high risk for asbestos-related diseases.[4,5] Several other occupations associated with significantly elevated PMRs have historically involved working with asbestos insulation (e.g., *boilermakers*; *plumbers, pipefitters, and steamfitters*; *heating, air conditioning, and refrigeration mechanics*; and *sheet metal workers*). Approximately 96% of all U.S. asbestosis deaths have occurred among men, reflecting the historical predominance of males employed in occupations and industries involving substantial asbestos exposure. Asbestosis decedents in the U.S. have been disproportionally white, again probably reflecting past racial pattern in asbestos-associated trades in this country and a potential differential reporting by race.[48]

During the period for which we analyzed U.S. death data, coding of diseases changed twice due to ICD revisions. The ICD revision from ICD-8 (used during 1970–1978) to ICD-9 (used during 1979–1998) had no impact on coding of asbestosis other than a change in the code numbering. In both of these versions, the rubric remained "asbestosis."[16,17] The ICD-10 revision (used since 1999) included a revision of the relevant rubric to "pneumoconiosis due to asbestos and other mineral fibers." While this change could possibly have biased ICD-10 coding of asbestos deaths relative to ICD-8 and ICD-9 coding, we feel that any substantive bias is highly unlikely. Following established methods for comparing ICD-10 to ICD-9,[49] the comparability ratio for "asbestosis" is 1.0056 (A. Manino, NCHS, personal communication), indicating a very close agreement (within about 0.5%) between the two revisions. In summary, the temporal trend in asbestosis deaths shown in Figure 1 is unlikely to have been substantively impacted by ICD revisions.

The state and county of residence at death do not always reflect the location in which a decedent's causative exposure occurred. For example, an asbestos-exposed insulator whose exposure was from shipyards in Virginia may have moved after retirement to Florida before dying of asbestosis. It is possible that elevated asbestosis death rates in some geographic areas have little bearing on past potential asbestos exposures in that same area. However, a study by Steenland and Beaumont reported that 78.0% of the individuals died in the states in which they worked.[50] Nevertheless, the generally coastal pattern of asbestosis deaths meets prior expectation based on existing awareness of the high risk associated with shipyard work.

Computerized and quality-checked data on usual industry and occupation of decedents is not available nationally in the U.S. Such data are limited to the 1985–1999 period, and are only available for some states in the U.S. Accuracy of industry and occupation associated with asbestosis on death certificates has not been examined, but several studies reported a relatively good agreement of this information on death certificates compared with that from other sources.[50–52] Steenland and Beaumont found that the accuracy of industry and occupation listed on death certificates was 70.1% and 64.7%, respectively among 2,198 long-term workers who had 10 or more years of work experience.[50] In addition, the usual industry and occupation reported on the death certificate may not have been the industry and occupation in which the decedent's causative exposure occurred. For example, a decedent who had worked as an insulator for 7 years and then as a truck driver for 23 years before dying of asbestosis, would likely have truck driver, not insulator, listed as usual occupation on his death certificate. If commonplace, such coding of usual industry and occupation is likely to bias PMR analyses to the null. Nevertheless, the PMR analyses identified many industries and occupations that would be expected to have been associated with high risk of asbestos exposure based on *a priori* expectations.

Asbestos has been and continues to be an occupational and environmental hazard of catastrophic proportion. In the U.S., more than 25,000 asbestosis deaths—and many more deaths from other asbestos-related diseases not discussed in this report—have occurred over the 35 years from 1970 to 2004. After a prolonged and marked increase from 1970 to 2000, the asbestosis death rate in the U.S. has declined slightly after 2000, probably related to declines in asbestos usage and exposure. We intend to maintain surveillance of asbestosis deaths in the U.S. to determine whether this recent decline continues.

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*References*


1. Steele MP, Peterson MW, Schwartz DA. Asbestosis and asbestos-induced pleural fibrosis. In: Schwarz MI, King TE (eds). Interstitial Lung Disease. 4th ed. London: BC Decker Inc., 2003:418–434.
2. De Vuyst P, Gevenois PA. Asbestosis. In: Hendrick DJ, Burge PS, Beckett WS, Churg A (eds). Occupational Disorders of the Lung: Recognition, Management, and Prevention. New York, NY: WB Saunders, 2002:143–162.
3. Landrigan PJ, Soffritti M. Collegium Ramazzini call for an international ban on asbestos. Am J Ind Med. 2005;47:471–474.
4. Nicholson WJ, Perkel G, Selikoff IJ. Occupational exposure to asbestos: population at risk and projected mortality—1980–2030. Am J Ind Med. 1982;3:259–311.
5. Selikoff IJ, Hammond EC, Seidman H. Mortality experience of insulation workers in the United States and Canada, 1943–1976. Ann NY Acad Sci. 1979;330:91–116.
6. Kgalamono SM, Rees D, Kielkowski D, Solomon A. Asbestos in the non-mining industry on the Witwaterstrand, South Africa. S Afr Med J. 2005;95:47–51.
7. Rom WN. Asbestos-related diseases. In: Rom WN (ed). Environmental Occupational Medicine. 3rd ed. New York, NY: Lippincott-Raven, 1998:349–375.
8. Becklake MR, Cowie RL. Pneumoconiosis. In: Murray JF, Nadel JA (eds). Textbook of Respiratory Medicine. 3rd ed. Philadelphia, PA: WB Saunders Company, 2000: 1811–1851.
9. Nicholson WJ, Selikoff IJ, Seidman H, Lilis R, Formby P. Long-term mortality experience of chrysotile miners and millers in Thetford Mines, Quebec. Ann N Y Acad Sci. 1979;330:11–21.
10. O'Reilly KM, Mclaughlin AM, Beckett WS, Sime PJ. Asbestos-related lung disease. Am Fam Physician. 2007;75:683–688.
11. Wagner GR, Hearl FJ. Mineral dusts: asbestos, silica, coal, manufactured fibes. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA (eds). Textbook of Clinical Occupational and Environmental Medicine. 2nd edition. New York: Elsevier Inc., 2005:1073–1086.
12. U.S. Department of Labor. Better protection against asbestos in the workplace. Fact Sheet No. OSHA 92-06. Available at: http://www.pp.okstate.edu/ehs/training/OSHASBES.HTM (accessed on August 27, 2007).
13. U.S. Geological Survey. Mineralogy and morphology of amphiboles observed in soils and rocks in El Dorado Hills, Californaia. Open-file report 2006–1362, 2006. Available at: http://pubs.usgs.gov/of/2006/1362/downloads/pdf/OF06-1362_508.pdf (accessed on August 27, 2007).
14. Asbestos ban: towards a European consensus (III). Asbestos-free Europe next stop? Available at: http://hesa.etui-rehs.org/uk/newsletter/files/1998-10-p02.pdf (accessed on August 27, 2007).
15. National Institute for Occupational Safety and Health (NIOSH). National Occupational Respiratory Mortality System (NORMS). Available at: http://webappa.cdc.gov/ords/norms.html.
16. U.S. Department of Health, Education, and Welfare: Eighth Revision International Classification of Diseases, adapted for use in the United States, Public Health Service Publication No. 1693, ICDA Volume 1, 1967.
17. U.S. Department of Health and Human Services, Public Health Service, Health Care Financing Administration. Official version ICD-9-CM. International Classification of Diseases, 9th Revision: Clinical modification fourth edition, 1988.
18. WHO. International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, 1992.
19. U.S. Department of Commerce, Economic and Statistics Administration, Bureau of the Census, 1992. Classified Index of Industries and Occupations, U.S. Government Printing Office, Washington, DC.
20. Bailar JC, Ederer F. Significance factors for the ratio of a Poisson variable to its expectation. Biometrics. 1964;20:639–643.
21. Virta RL. Mineral Commodity Profiles—Asbestos. U.S. Geological Survey Circular 1255–KK, 2005. Available at: http://pubs.usgs.gov/circ/2005/1255/kk/Circ_1255KK.pdf (accessed on March 1, 2007).
22. American Lung Association (ALA). Asbestos October 2006. Available at: http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=35368 (accessed on June 18, 2007).
23. U.S. Environmental Protection Agency. EPA Asbestos Materials Bans: Clarification. Available at: http://www.epa.gov/oppt/asbestos/pubs/asbbans2.pdf (accessed on August 8, 2007).
24. U.S. Senator Patty Murray. Murray's asbestos bill passes key committee with unanimous, bipartisan support. News release, July 31, 2007. Available at: http://murray.senate.gov/news.cfm?id=280072 (accessed on August 6, 2007).
25. Martonik JF, Nash E, Grossman E. The history of OSHA's asbestos rulemakings and some distinctive approaches that they introduced for regulating occupational exposure to toxic substances. AIHAJ. 2001;62:208–217.
26. National Archives and Records Administration (NARA). Code of Federal Regulations 29, Part 1910.1001 Asbestos. Occupational Safety and Health Administration, July 1, 2003.
27. National Institute for Occupational Safety and Health. Work-Related Lung Disease Surveillance Report 2002. DHHS (NIOSH) Number 2003-111, May 2003.
28. Smartt P. Mortality, morbidity, and asbestosis in New Zealand: the hidden legacy of asbestos exposure. N Z Med J. 2004; 117:U1153.
29. Berry G. Prediction of mesothelioma, lung cancer, and asbestosis in former Wittenoom asbestos workers. Br J Ind Med. 1991; 48:793–802.
30. Kjellstrom T, Smartt P. Increased mesothelioma incidence in New Zealand: the asbestos–cancer epidemic has started. N Z Med J. 2000;113:485–490.
31. Peto J, Decarli A, La Vecchia C, Levi F, Negri E. The European mesothelioma epidemic. Br J Cancer. 1999;79:566–572.
32. Peto J, Hodgson JT, Matthews FE, Jones JR. Continuing increase in mesothelioma mortality in Britain. Lancet. 1995;345: 535–539.
33. Albin M, Magnani C, Krstev S, Rapiti E, Shefer I. Asbestos and cancer: An overview of current trends in Europe. Environ Health Perspect. 1999;107 Suppl 2:289–298.
34. Treasure T, Waller D, Swift S, Peto J. Radical surgery for mesothelioma. BMJ. 2004; 328:237–238.
35. Hodgson JT, McElvenny DM, Darnton AJ, Price MJ, Peto J. The expected burden of mesothelioma mortality in Great Britain from 2002 to 2050. Br J Cancer. 2005;92:587-593.
36. National Occupational Health and Safety Commission. The incidence of mesothelioma in Australia, 1999 to 2001.Australian Mesothelioma Register Report 2004: November 2004. Available at: http://www.ascc.gov.au/NR/rdonlyres/93D1C861-CFCD-4A3E-9F1B-B445083FB30E/0/meso2004.pdf (accessed on July 20, 2007).
37. Smith DR, Leggat PA. 24 years of pneumoconiosis mortality surveillance in Australia. J Occup Health. 2006;48:309–313.
38. Oksa P, Suoranta H, Koskinen H, Zitting A, Nordman H. High–resolution computed tomography in the early detection of asbestosis. Int Arch Occup Environ Health. 1994;65:299–304.
39. Genenois PA, De Vuyst P, Dedeire S, Cosaert J, Vande Weyer R, Struyven J. Conventional and high-resolution CT in asymptomatic asbestos-exposed workers. Acta Radiol. 1994;35:226–229.
40. Aberle DR, Gamsu G, Ray CS, Feuerstein IM. Asbestos-related pleural and parenchymal fibrosis: detection with high-resolution CT. Radiology. 1988;166:729–734.
41. Friedman AC, Fiel SB, Fisher MS, Radecki PD, Lev-Toaff AS, Caroline DF. Asbestos-related pleural disease and asbestosis: a comparison of CT and chest radiography. AJR Am J Roentgenol. 1988;150:269–275.
42. Goraya TY, Jacobsen SJ, Belau PG, Weston SA, Kottke TE, Roger VL. Validation of death certificate diagnosis of out-of-hospital coronary heart disease deaths in Olmsted County, Minnesota. May Clin Proc. 2000;75:681–687.
43. Rosenman KD, Reilly MJ, Henneberger PK. Estimating the total number of newly-recognized silicosis cases in the United States. Am J Ind Med. 2003;44:141–147.
44. Carroll SJ, Hensler D, Gross J, et al. Asbestos litigation. Rand Institute for Civil Justice, RAND Corporation, Santa Monica, 2005. Available at: http://www.rand.org/pubs/monographs/2005/RAND_MG162.sum.pdf (accessed on August 6, 2007).
45. Hinton P, Miller R, Sabry F, Dunbar F. Where are mesothelioma claims heading? NERA Economic Consulting, December 7, 2006.

46. Sullivan PA. Vermiculite, respiratory disease and asbestos exposure in Libby, Montana: Update of a cohort mortality study. Environ Health Persp. 2007;115:579–585. Available at: http://www.ehponline.org/members/2007/9481/9481.pdf.
47. Weeks JL, Christiani DC. Asbestos-related diseases. In: Levy BS, Wagner GR, Rest KM, Weeks JL (eds). Preventing Occupational Disease and Injury. 2nd ed. Washington: American Public Health Association. 2005:93–97.
48. Rockett IR, Samora JB, Coben JH. The black-white suicide paradox: possible effects of misclassification. Soc Sci Med. 2006; 63:2165–2175.
49. Anderson RN, Minino AM, Hoyert DL, Rosenberg HM. Comparability of cause of death between ICD-9 and ICD-10: Preliminary estimates. National Vital Statistics Reports. 2001;49:1–32.
50. Steenland K, Beaumont J. The accuracy of occupation and industry data on death certificate. J Occu Med. 1984; 26:288–296.
51. Gute DM, Fulton JP. Agreement of occupation and industry data on Rhode Island death certificates with two alternative sources of information. Public Health Rep. 1985;100:65–72.
52. Schumacher MC. Comparison of occupation and industry information from death certificates and interviews. Am J Public Health. 1986;76:635–637.