Too Soon to Breathe Easy

Trends in Asbestosis Morbidity and Mortality in Wisconsin

Paul D. Creswell, PhD, Katherine E. McCoy, PhD, Komi K.S. Modji, MD, MPH, CPH, Collin R. Morris, BS, and Sheryl Bedno, MD, DrPH

Objectives: This study aimed to describe asbestosis morbidity and mortality in two statewide samples. We considered trends, demographic disparities, and excess mortality. **Methods:** We assessed trends and demographic differences in asbestosis morbidity using hospital and emergency department (ED) visits. We calculated asbestosis mortality rates using vital records data and computed proportional mortality ratios (PMRs) to assess excess deaths by standardized industry and occupation codes. **Results:** Asbestosis diagnoses peaked in 2008 and have declined since that time. Several occupations and industry codes, including those in Production/Manufacturing, Construction, and Transportation, were associated with an excess burden of asbestosis mortality. **Conclusions:** Despite declining diagnoses, asbestosis remains a risk for workers. Our findings of excess mortality for Transportation-related industry and occupation codes are unique and may indicate previously unrecognized risks in these jobs.

Keywords: epidemiology, hazardous exposures, occupational/environmental disease

From the Occupational Health Safety and Surveillance Program, Bureau of Environmental and Occupational Health, Wisconsin Department of Health Services, Madison, Wisconsin (P.D.C., K.E.M., K.K.S.M., C.R.M., S.B.); and Department of Population Health Sciences, School of Medicine and Public Health, University of Wisconsin—Madison, Madison, Wisconsin (P.D.C., K.K.S.M.)
ORCID: http://orcid.org/0000-0001-8432-0017
ORCID: http://orcid.org/ 0000-0001-8939-8550
ORCID: http://orcid.org/0000-0001-8156-6767
ORCID: http://orcid.org/0000-0002-9775-2393
ORCID: http://orcid.org/0000-0002-2519-8872
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Address correspondence to: Paul D. Creswell, PhD, Occupational Health Safety and Surveillance Program, Bureau of Environmental and Occupational Health, Wisconsin Department of Health Services, 1 West Wilson St, Room 150, Madison, WI 53703 (pdcreswell@wisc.edu).

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LEARNING OUTCOMES

After reading this article, the reader should be better able to:

- Describe the direction of trends in asbestosis morbidity (ie, diagnoses) in a statewide sample.
- Identify industries and occupations that are associated with excess mortality from asbestosis in a statewide sample.
- Describe the role of clinicians in occupational public health surveillance for diseases such as asbestosis.

Asbestosis is a form of pneumoconiosis (ie, work-related interstitial fibrosis of the lung) caused by inhalation of asbestos fibers and is a risk for workers in many industries and occupations.[1–4] Pneumoconioses such as asbestosis also contribute to cancers and other diseases including mesothelioma, lung cancer, chronic obstructive pulmonary disease (COPD), tuberculosis, congestive heart failure, and autoimmune diseases.[5,6] Despite these risks and ongoing sources of exposure, in the United States, there are relatively few systematic efforts to track asbestos exposures and related morbidity and mortality for public health surveillance.

Historically, because of its heat-resistant properties, asbestos was a valuable commercial product. In the middle-ages, asbestos, seen as a miracle fiber, was associated with salamanders, which were mistakenly believed to be fireproof.[7] This connection persists in the logos of insulators' unions to this day.[8] In the 20th century, as the negative health effects of asbestos exposure became increasingly evident, the product was banned in the European Union and many other countries.[1] In the United States, usage peaked in the 1970s and has declined since that time, in part due to state and federal regulations.[1,9]

Asbestos mining in the United States ceased in 2002[10] and in March of 2024, the EPA announced a ban on chrysotile asbestos and plans to phase out remaining industrial uses (eg, chlorine production, brake blocks, and after-market brake pads).[11] In recent years, many exposures to asbestos in the United States are from legacy sources of asbestos in myriad building and infrastructure materials.[12] Disease arising from these existing sources of exposure is considered a "third wave" of asbestos-related disease, with the first two waves due to asbestos mining and active asbestos usage by insulators and shipbuilders, respectively.[12]

National statistics show that cases of asbestosis and asbestosis-related mortality rose in tandem from the late 1960s to the year 2000 and then leveled off.[1,13] Since the early 2000s, evidence suggests a decline in asbestosis-related mortality[14] and hospitalizations,[2] although asbestosis still accounts for approximately three-fifths of deaths among pneumoconioses[14] and trends have different latency by age cohort.[3,5,15]

Wisconsin, a state in the Midwest of the United States, has been shown to have relatively low rates of asbestosis.[2] However, reporting of trends has been limited, and there remain important gaps in our understanding of asbestosis in the state. These limitations in understanding are unfortunate given that Wisconsin has a strong history of

manufacturing and one of the major handlers of asbestos, The Johns-Manville Corporation, had facilities in Wisconsin's largest city, Milwaukee.[16] Although asbestosis is a reportable condition in Wisconsin, meaning that physicians and clinics are required to report cases to the state,[17] in practice, this reporting does not always happen. Moreover, Wisconsin has only had systematic surveillance of occupational diseases and disorders for roughly two decades.[18] The goal of the present analysis is to assess trends of asbestosis diagnoses and mortality in Wisconsin, consider disparities by demographics, and assess which occupations and industries in the state are associated with burden.

METHODS

Data Sources

Our analyses use administrative data taken from statewide public health surveillance systems. As such, individual informed consent and IRB approval were not required or obtained. These analyses were performed as part of our normal duties as members of the State of Wisconsin's public health workforce. This work conforms to the principles delineated in the Declaration of Helsinki, and we have made every effort to preserve confidentiality, including suppressing counts in tables when <5 individuals are represented. We have included, as Supplemental Digital Content (http://links.lww.com/JOM/B736), a Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for this study.

To assess trends in asbestosis morbidity, we analyzed Wisconsin hospital and emergency department (ED) visit data from the Wisconsin Department of Health Services (WI-DHS). Inpatient and ED visits where asbestosis is indicated are indicative of asbestosis morbidity, even if some diagnoses (ie, those only seen in an outpatient setting) are not captured. The period under consideration is January 1, 1989, to December 30, 2023 — a period comprising all available data at the time of analysis. The data set covers all Wisconsin hospitals and EDs, with the exception of federal hospitals (eg, VA hospitals), on a quarterly basis, which includes patient diagnoses and demographics.

To assess trends in asbestos-related mortality, we used Wisconsin vital records data from January 1, 2014, to December 31, 2023. Vital records for the state were digitized beginning in 2014, and the data set captures all deaths in Wisconsin annually. Death data are collected and reported by individual medical examiners and coroners by county.[19] Death records include information on the cause of death (including contributing causes), the date of death, and demographic variables, including free text entries for usual occupation.

The usual occupation information captured in vital records was converted into standardized codes for analysis using the National Institute for Occupational Safety and Health (NIOSH) Industry and Occupation Computerized Coding System (NIOCCS) autocoder.[20] The NIOCCS autocoder allows for conversion of free-text occupation and industry records into Standard Occupational Classification (SOC) (2018) and North American Industry Classification System (NAICS) (2017) codes. Additional details on these codes are available from the US Bureau of Labor Statistics.[21,22]

Denominators for the calculation of all rates were obtained from the American Community Survey (ACS)[23] via the University of Minnesota's Integrated Public Use Microdata Series (IPUMS) platform at the Institute for Social Research and Data Innovation.[24] To calculate diagnosis rates for hospital discharges by year, we used individual yearly estimates from ACS. No ACS population estimate is available for 1989. As such, the 1990 population estimate was also applied in that year. To calculate the diagnosis rates for grouped years, we used the most recent ACS 5-year estimates available at the time of analysis (ie, 2017–2021). For the mortality analysis, we used ACS 2000 estimates for working age adults (ages 18–65 years) to account for some of the lag in asbestos exposure and the development of asbestosis.[3,5] As asbestosis mortality occurs many decades postexposure,[15] we believe that the working-age population of Wisconsin in 2000 makes a better reference population for asbestosis mortality in our analysis than recent estimates. As a sensitivity check, a version of the analysis was also run using the 2021 5-year ACS estimate and no meaningful differences were found.

Classification of Asbestosis Cases

Asbestosis diagnoses in hospital and ED data were based on a review of all diagnosis fields. Diagnoses were obtained using either International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), or International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes. Prior to quarter four of 2015, the ICD-9-CM code 501 (ie, "pneumoconiosis due to asbestos") was used. Beginning in quarter four of 2015, ICD-10-CM code J61 (ie, "pneumoconiosis due to asbestos and other mineral fibers"), which replaced ICD-9-CM 501, was used. Additionally, we included ICD-10-CM code J92.0 (ie, "pleural plaque with presence of asbestos"), which is exclusive of J61 and has no ICD-9-CM analogue. For the purposes of these analyses, any of these three codes indicated a diagnosis of asbestosis.

Classification of Asbestosis Deaths

Asbestosis mortality was classified in the vital records data set using a triangulation of methods. First, we included all deaths with ICD-10-CM codes J61 or J92.0 in the cause of death or contributing causes of death. Next, we included records without such diagnoses but with indications of asbestosis in the free text cause of death field, as well as free text contributing cause of death fields. If "asbestosis" was included in the cause of death or other significant condition fields, the death was kept for the analysis. Additionally, we included cases where the term "asbestos" was found in the cause of death or contributing cause of death fields but only when this term was paired with one of the following terms/phrases: "asbestos lung," "interstitial," "lung disease," "pleural," "asbestos related," "pulmonary fibrosis," "pneumoconiosis," or "trapped lung."

Analytical Samples

The asbestosis morbidity sample included individuals in Wisconsin who were seen in the hospital or ED with a diagnosis of asbestosis from January 1, 1989, through December 30, 2023 (N = 4516). The mortality sample included all causes of death so that the proportion of deaths attributed to asbestosis could be calculated overall and by industry and occupation. The asbestosis mortality sample therefore included decedents aged >45 years who were recorded in the vital records data from January 1, 2014, through December 31, 2023 (N = 532,359), 0.4% of whom had an asbestosis death (N = 222). Decedents younger than 45 years were excluded as they were unlikely to die from asbestosis and the inclusion of younger decedents not at risk of asbestosis deaths would artificially dilute the impact of asbestosis on the population at risk.

Statistical Analyses

To evaluate incidence of asbestosis diagnoses in Wisconsin over 35 years, we assessed year to year incident count and rate trends using the coefficient of determination (R^2). In order to evaluate the relative burden of asbestosis mortality, we used continuity corrected χ^2 tests[25] to assess the proportion of asbestosis deaths compared to deaths by all other causes stratified by demographic characteristics. We then used multivariate logistic regression to evaluate the likelihood of an asbestosis death by demographics in our sample of decedents while controlling for confounders. Mortality rates were also calculated to evaluate differences in burden across industry and occupation categories.

Proportional mortality ratios (PMRs) were calculated to assess the within-group burden of asbestosis mortality by occupation and

industry. PMRs represent the proportion of deaths due to asbestosis in any SOC or NAICS category divided by the proportion of asbestosis deaths among all other workers multiplied by 100.[26] PMRs greater than 100 indicate excess mortality and 95% confidence intervals (95% CIs) above 100 at the lower-bound indicate statistical significance. For our analysis, we considered PMRs unstable when an industry or occupation category had fewer than 15 asbestosis deaths in the time period under study.

RESULTS

Morbidity Demographics

Among those identified with asbestosis in the hospital and ED data who had recorded demographic information, 98% were White, 99.7% were non-Hispanic, and 95.8% were male (data not shown). With regard to age, 43.2% of the sample was aged 46 to 75 years, 41.5% was aged 76 to 85 years, and 15.4% was aged 86 years or more (data not shown).

Trends in Morbidity

Rates of asbestosis per 100,000 individuals in our hospital and ED sample increased from 0.98 in 1989 to 4.38 in 2008, before declining again to 0.73 in 2023. Both the increasing and decreasing trends had robust fits with the trend data ($R^2 = 0.794$ and 0.919, respectively) (Fig. 1).

Mortality Demographics

χ^2 Tests of association, which assess the difference in proportions (actual vs expected), indicated that asbestosis decedents were significantly more likely to be older and male and have lower levels of education than other decedents in Wisconsin in the period under study (Table 1). Decedents were also more than 99% White and non-Hispanic (data not shown) with only two non-White individuals and only one Hispanic individual identified as having asbestosis. Similar to the hospital/ED sample, the majority of the sample was male (97.3%). However, this sample skewed older than the hospital/ED sample with 15.8% aged 46 to 75 years, 44.6% aged 66 to 75 years, and 39.6% aged 86 years or more (Table 1).

Table 2 presents the results of the multivariate logistic regression analysis we conducted to assess the likelihood of asbestosis death by demographic factors while controlling for other covariates. Race and ethnicity variables were not included in this model due to lack of variation (see previous paragraph). As in the bivariate analysis, age, sex, and education were significantly associated with asbestosis mortality. Compared to the oldest decedents, those 75 years or younger were significantly less likely to have an asbestosis death (Table 2). Females were far less likely to die from asbestosis (OR, 0.02; 95% CI, 0.01–0.05) as were those with higher levels of education. Having some college, an associate's, a bachelor's, or an advanced degree was associated with a 47% reduction in the likelihood of dying from asbestosis (OR, 0.53; 95% CI, 0.39-0.71).

Mortality Rates

We calculated mortality rates per 100,000 for Wisconsin decedents by usual occupation and industry. Five occupations had significantly elevated asbestosis mortality rates while also having case counts sufficient for rate stability (Table 3). These were Construction and Extraction (35.36; 95% CI, 26.34–44.38); Installation, Maintenance, and Repair (21.49; 95% CI, 12.90–30.09); Transportation and Material Moving (11.30; 95% CI, 6.68–15.92); Production (9.68; 95% CI, 6.68–12.67); and Management (8.69; 95% CI, 5.14–12.25). Three industries also had significantly elevated rates of asbestosis mortality per 100,000 decedents and sufficient counts for rate stability (Table 4). These were Construction (27.77; 95% CI, 20.30–35.25); Transportation and Warehousing (17.30; 95% CI, 9.72–24.88); and Manufacturing (9.67; 95% CI, 7.24–12.10).

Proportional Mortality Ratios

Occupation

Table 5 provides PMRs by major occupation code for working-age Wisconsin decedents during the period under study. For occupations with PMRs determined to be stable (ie, numerator ≥15 and denominator ≥100), the highest were found for Construction and Extraction (PMR, 521.26; 95% CI, 477.76–567.27); Installation, Maintenance, and Repair (PMR, 328.86; 95% CI, 294.27–365.34); Production (PMR, 160.51; 95% CI, 136.64–186.28); and Transportation and Material Moving (PMR, 125.74; 95% CI, 104.72–148.65). Protective Service occupations also had a significantly elevated PMR (Table 5), but this value should be considered with caution given the number of cases used to calculate the rate value of the ratio's numerator (n = 9).

Industry

Three major industry groups also had significantly elevated and stable PMRs (Table 6). These included Construction (PMR, 414.24; 95% CI, 477.76–567.27); Transportation and Warehousing (PMR, 197.80; 95% CI, 171.20–226.30); and Manufacturing (PMR, 142.53;

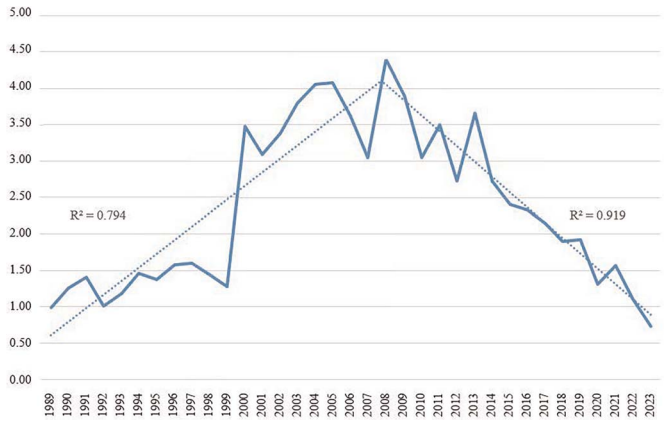

FIGURE 1. This figure shows rates of asbestosis diagnosis per 100,000 population over time in Wisconsin. The *y* axis shows the possible rates from zero to 5 per 100,000 population. The *x* axis shows the possible years from 1989 through 2023. In 1989, the rate is 0.98 per 100,000 and the rate changes each year, but with a general upward trend, until 2008 when it is 4.38. After 2008, the rate has a general downward trend until 2023 at which point it is 0.73 per 100,000.

TABLE 1. Demographic Characteristics of Individuals With Asbestosis Mortality Versus All Deaths — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 532,353)

	Asbestosis	Other Causes		
	n = 222 (%)	n = 532,131 (%)	χ^2	*P* Value
Age				
46 to 75 y	35 (15.8)	210,142 (39.5)	60.3	<0.0001
76 to 85 y	99 (44.6)	142,354 (26.7)		
86+ y	88 (39.6)	179,635 (33.7)		
Sex*				
Female	6 (2.7)	264,202 (49.7)	195.6	<0.0001
Male	216 (97.3)	267,928 (50.4)		
Education				
Less than high school	52 (23.5)	84,726 (16.1)	20.3	<0.0001
High school graduate or GED	122 (55.2)	259,443 (49.4)		
Some college, associate's, bachelor's, or advanced degree	47 (21.3)	181,389 (34.5)		
Missing or unknown	1	6573		

*Excludes sex "unknown" (n = 1).

95% CI, 120.09–166.87). Four other industries — Utilities, Wholesale Trade, Public Administration, and Agriculture, Forestry, Fishing, and Hunting — had significantly elevated PMRs (Table 6), but these values should be viewed with caution given the relatively small number of cases used in the calculations (ie, n = 6, n = 5, n = 12, and n = 12 cases, respectively).

Subgroup Drivers

A few minor SOC and three-digit NAICS categories drove some of the PMRs at the major SOC and two-digit NAICS levels. For instance, more than half of the cases in the Transportation and Material Moving Occupations category (Table 5) were in the minor SOC category of Motor Vehicle Operators (n = 11; PMR, 150.93; 95% CI, 127.81–175.94) (data not shown). Additionally, these cases overlapped substantially with the three-digit NAICS category of Truck Transportation (n = 10; PMR, 204.99; 95% CI, 177.89–233.99), which was the primary driver of the significant PMR in the Transportation and Warehousing Industry (Table 6). Similarly, although Production Occupations accounted for nearly one fifth of all asbestosis deaths in our sample, the majority of those cases were from the minor SOC categories of Metal Workers and Plastic Workers (n = 14; PMR, 190.97; 95% CI, 164.85–218.99) and Other Production Occupations (n = 16; PMR, 250.4; 95% CI, 220.35–282.35) (data not shown). Within Construction and Extraction Occupations, 92% of cases were from the minor SOC category of Construction Trades Workers (n = 53; PMR, 537.49; 95% CI, 493–583.87) (data not shown).

DISCUSSION

Asbestosis remains a risk for some workers in Wisconsin, although our study shows significantly decreasing trends in diagnosis since 2008. These declining trends parallel findings, which suggest that asbestosis diagnoses are decreasing nationally.[14] It is important to note that we cannot definitively say what is causing these declines. Certainly, the restrictions on asbestos usage over time are relevant as they would imply decreasing exposure risk. At the same time, other factors may also have affected asbestosis awareness and therefore detection. For instance, some literature suggests that high profile lawsuits, and their subsequent drop-off, may affect diagnosis trends in recent decades.[1]

Our findings show that sex, age, and education are associated with asbestosis mortality. Women were much less likely to die from this cause than men, which likely reflects the historical differences in the gender makeup of the labor force for asbestos exposed workers. We also found stratification by education such that, compared to those with a high school education, those with higher levels of education had lower likelihoods of asbestosis mortality. This also reflects the way higher education correlates with different kinds of labor force activities and demonstrates the continued need to recognize work as a social determinant of health and health disparities.[27,28] Finally, those in the oldest age categories were most likely to die from this disease, which reflects what is known about the latency of disease development post-exposure.[15]

Morbidity

The declines in asbestosis diagnoses shown here align with those of other studies and likely reflect reduced exposure to asbestos in recent decades. At the same time, it is worth considering the extent to which other factors may have affected this decline in diagnoses. The number of board-certified occupational health physicians in Wisconsin, as indicated by the membership rolls of the American College of Occupational and Environmental Medicine (ACOEM), has decreased in recent years from a peak of 65 physicians in 2009 to only 10 in 2023.[29–31] This change parallels declines in occupational medicine training programs for physicians throughout the US,[32] including Wisconsin, which is presently without a physician training program. This trend of fewer occupational health physicians practicing in the state could have contributed to the apparent decline in asbestosis morbidity if it had the unintended effect of making asbestosis cases less likely to be detected or more likely to be misdiagnosed. It is interesting to note that a Canadian study found that differential incentives could lead physicians to choose one diagnosis over another (eg, pulmonary fibrosis vs asbestosis or silicosis),[33] which points to another mechanism by which changes in clinician reporting could account for changing morbidity over time.

In contrast, as mentioned previously, the ICD-10-CM code J61 now includes "other mineral fibers," whereas the ICD-9-CM code 501 did not — a discontinuity that could also affect diagnosis trends.[13] However, the one study that looked at the comparability ratio for ICD-10-CM to ICD-9-CM showed very close agreement, suggesting that this is unlikely to be a major problem.[1] Moreover, the addition of ICD-10-CM code J92.0 to our present analyses, which has no ICD-9-CM analogue, provides another opportunity for capturing additional cases in recent years. Given that these changes would each likely result in more case capture, our findings of declines in asbestosis diagnoses, all other things being equal, are likely conservatively estimated.

TABLE 2. Multivariate Logistic Regression Analysis of Individual Characteristics Associated With Asbestosis Mortality — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 525,779)*

	Odds Ratio (95% Confidence Interval)
Age	
46 to 75 y	0.32 (0.23–0.44)
76 to 85 y	1.11 (0.85–1.45)
86+ y	Reference
Sex	
Female	0.02 (0.01–0.05)
Male	Reference
Education	
Less than high school	0.98 (0.72–1.33)
High school graduate or GED	Reference
Some college, associate's, bachelor's, or advanced degree	0.53 (0.39–0.71)

*Excludes sex and education "unknown" or "missing" (n = 6574).

TABLE 3. Asbestosis Attributable Deaths, ACS Denominator Estimates (2000), and Asbestos-Related Mortality Rates by Major SOC Code — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 532,353)

Major SOC Code	Asbestosis-Attributable Deaths (n = 222)	ACS 2000 Denominator Estimate (n = 3,265,111)	Mortality Rate (95% Confidence Intervals)
Construction and Extraction Occupations	59	166,873	35.36 (26.34–44.38)
Installation, Maintenance, and Repair Occupations	24	111,663	21.49 (12.90–30.09)
Protective Service Occupations*	9	47,576	18.92 (6.56–31.28)
Transportation and Material Moving Occupations	23	203,467	11.30 (6.68–15.92)
Production Occupations	40	413,435	9.68 (6.68–12.67)
Management Occupations	23	264,582	8.69 (5.14–12.25)
Sales and Related Occupations*	7	271,808	2.58 (0.67–4.48)
Office and Administrative Support Occupations*	6	467,624	1.28 (0.26–2.31)
Architecture and Engineering Occupations	†	56,649	—
Arts, Design, Entertainment, Sports, and Media Occupations	†	44,571	—
Building and Grounds Cleaning and Maintenance Occupations	†	106,845	—
Business and Financial Operations Occupations	†	123,615	—
Educational Instruction and Library Occupations	†	167,732	—
Farming, Fishing, and Forestry Occupations	†	23,014	—
Food Preparation and Serving-Related Occupations	†	178,103	—
Healthcare Practitioners and Technical Occupations	†	135,317	—
Healthcare Support Occupations	†	67,820	—
Community and Social Service Occupations		38,659	—
Computer and Mathematical Occupations		56,242	—
Life, Physical, and Social Science Occupations		202,067	—
Legal Occupations		16,139	—
Personal Care and Service Occupations		81,727	—
Missing or Unknown Occupation*	12	202,067	5.94 (2.58–9.30)

*Numerator <15 and/or denominator <100 denoting rate instability.
†Counts <5 suppressed.

Even with the decline in asbestosis diagnoses, it remains important to monitor trends in this disease. Evidence shows that hospital discharges likely underestimate the number of asbestosis cases due to the lack of data from outpatient clinics.[34] Wisconsin is among the states instituting electronic case reporting (eCR), a method by which reportable conditions are flagged and sent directly to health departments via electronic health records (EHRs), which should remedy this issue and improve the accuracy of asbestosis surveillance in the future.[35] Moreover, as demonstrated by the recent increase of acute silicosis among individuals working with manufactured stone,[36] industrial exposures that lead to pneumoconioses are still present in many work environments. Careful monitoring allows for early detection of new or previously unrecognized exposure scenarios.

Mortality

In terms of asbestosis mortality, our study shows that some occupations and industries continue to bear a higher burden and indicate areas of focus for outreach and prevention efforts. The top occupations with significant excess mortality as indicated by PMRs and 95% CIs above 100 (Table 5) were (1) Construction and Extraction; (2) Installation, Maintenance, and Repair; (3) Production; and (4) Transportation and Material Moving occupations. Most of these findings are in keeping with extant literature on asbestosis,[14,37] whereas the higher PMR for Transportation and Material Moving is a new finding.

Construction continues to impose risks on workers due to the presence of asbestos in existing structures.[12,33,37] In many construction or demolition scenarios, it is not possible to use elimination or substitution, and workers must rely instead on engineering and other controls to reduce exposure.[38] Construction is a large industry, which accounts for roughly 5% of nonfarm wage and salary employment in Wisconsin,[39] and there is a reasonable likelihood of many workers continuing to be exposed in these jobs if demolition and remodeling are involved.[12] Additionally, the construction workforce in Wisconsin is becoming more diverse, with a substantial proportion of Latino/Hispanic workers and greater representation of women. Although we did not see increased risks of asbestosis morbidity or mortality for Hispanics or women in our analyses, future work should consider these groups because the changing workforce may convey new risks as time goes on.

Production Occupations accounted for a substantial proportion of cases in our analysis (nearly 20%) and were associated with both an elevated mortality rate and an elevated PMR. Specifically, the subcategories of Metal Workers and Plastic Workers and Other Production Occupations drove these findings. Production remains a major industry in Wisconsin, and previous studies have found that these occupations are associated with asbestosis risk.[14,37] Similarly, manufacturing is a major industry throughout Wisconsin that accounts for approximately 15% of nonfarm wage and salary employment.[39] Manufacturing has been found to be associated with both asbestos exposure and subsequent asbestosis.[3,14,40,41] As an industry, manufacturing overlaps substantially with production occupations, suggesting that those workers involved in manufacturing of plastics and metal are among those at highest risk.

Transportation and Material Moving Occupations were associated with excess mortality in our sample, and more than half of these cases were among the subcategory of Motor Vehicle Operators. Evidence suggests that brake pads provide a source of exposure to

TABLE 4. Asbestosis Attributable Deaths, ACS Denominator Estimates (2000), and Asbestos-Related Mortality Rates by Two-Digit NAICS Code — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 532,353)

Two-Digit NAICS Code	Asbestosis-Attributable Deaths (n = 222)	ACS 2000 Denominator Estimate (n = 3,265,111)	Mortality Rate (95% Confidence Intervals)
Construction	53	190,821	27.77 (20.30–35.25)
Utilities*	6	27,214	22.05 (4.41–39.69)
Transportation and Warehousing	20	115,600	17.30 (9.72–24.88)
Agriculture, Forestry, Fishing, and Hunting*	11	80,168	13.72 (5.61–21.83)
Manufacturing	61	630,768	9.67 (7.24–12.10)
Public Administration*	12	130,315	9.21 (4.00–14.42)
Other Services (except Public Administration)*	7	121,197	5.78 (1.50–10.05)
Wholesale Trade*	5	133,581	3.74 (0.46–7.02)
Educational Services*	8	242,476	3.30 (1.01–5.59)
Retail Trade*	7	299,357	2.34 (0.61–4.07)
Accommodation and Food Services	†	200,488	—
Administrative and Support and Waste Management and Remediation Services	†	79,243	—
Arts, Entertainment, and Recreation	†	49,170	—
Finance and Insurance	†	131,335	—
Health Care and Social Assistance	†	351,547	—
Information	†	68,509	—
Professional, Scientific, and Technical Services	†	97,347	—
Real Estate and Rental and Leasing	†	37,723	—
Missing or Unknown Industry*	10	278,252	3.59 (1.37–5.82)

*Numerator <15 and/or denominator <100 denoting rate instability.
†Counts <5 suppressed.

asbestos[42,43]; however, findings are mixed regarding asbestos-related health outcomes for brake mechanics.[40] The literature shows that Transportation and Material Moving Occupations are not being considered as at-risk groups. Only one study we found considered Motor Vehicle Operators as an at-risk group for asbestos exposure, and the findings did not suggest elevated risk.[44] Similarly, there is a lack of literature that considers Transportation and Warehousing Industry workers, although associations with lung cancer have been found for this group in at least one study.[45] Imported asbestos has historically been transported by either truck or rail, which is another potential exposure for this group. The lack of work in this area may reflect unexamined assumptions of which groups are primarily exposed to

TABLE 5. Asbestos-Related PMRs by Major SOC Code — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 532,353)

Major SOC Code	Asbestos-Related Deaths (n = 222)	All Other Deaths (n = 532,131)	Proportional Mortality Ratio (PMR) (95% Confidence Interval)
Construction and Extraction Occupations	59	27,115	521.56 (477.76–567.27)
Installation, Maintenance, and Repair Occupations	24	17,493	328.86 (294.27–365.34)
Protective Service Occupations*	9	6956	310.13 (276.57–345.59)
Production Occupations	40	59,733	160.51 (136.64–186.28)
Transportation and Material Moving Occupations	23	43,846	125.74 (104.72–148.65)
Management Occupations	23	55,668	99.03 (80.49–119.47)
Sales and Related Occupations*	7	35,905	46.73 (34.30–61.05)
Office and Administrative Support Occupations*	6	50,287	28.60 (19.09–39.99)
Architecture and Engineering Occupations*	†	11,018	—
Arts, Design, Entertainment, Sports, and Media Occupations*	†	6284	—
Building and Grounds Cleaning and Maintenance Occupations*	†	13,513	—
Business and Financial Operations Occupations*	†	12,038	—
Educational Instruction and Library Occupations*	†	25,006	—
Farming, Fishing, and Forestry Occupations*	†	2320	—
Food Preparation and Serving-Related Occupations*	†	15,779	—
Healthcare Practitioners and Technical Occupations*	†	18,551	—
Healthcare Support Occupations*	†	13,747	—
Community and Social Service Occupations		6563	—
Computer and Mathematical Occupations		3807	—
Legal Occupations		2194	—
Life, Physical, and Social Science Occupations*		3246	—
Personal Care and Service Occupations		6523	—
Missing or Unknown Occupations*	12	94,539	30.43 (20.59–42.15)

PMR, proportional mortality ratio.
*Numerator <15 and/or denominator <100 denoting rate instability.
†Counts <5 suppressed.

TABLE 6. Asbestos-Related PMRs by Two-Digit NAICS Code — Working-Age Wisconsin Decedents: January 1, 2014, to December 31, 2023 (N = 532,353)

Two-Digit NAICS Code	Asbestos-Related Deaths (n = 222)	All Other Deaths (n = 532,131)	Proportional Mortality Ratio (PMR) (95% Confidence Interval)
Construction	54	31,247	414.24 (375.30–455.07)
Utilities*	6	5345	269.07 (237.88–302.16)
Transportation and Warehousing	20	24,236	197.80 (171.20–226.30)
Wholesale Trade*	5	7878	152.13 (128.92–177.24)
Public Administration*	12	20,025	143.64 (121.11–168.06)
Manufacturing	64	107,629	142.53 (120.09–166.87)
Agriculture, Forestry, Fishing, and Hunting*	12	22,400	128.41 (107.16–151.55)
Other Services (except Public Administration)*	7	20,528	81.74 (64.98–100.38)
Educational Services*	9	38,144	56.56 (42.79–72.22)
Retail Trade*	7	36,870	45.51 (33.26–59.65)
Health Care and Social Assistance*	5	47,940	25.00 (16.18–35.71)
Accommodation and Food Services*	†	18,208	—
Administrative and Support and Waste Management and Remediation Services*	†	7843	—
Arts, Entertainment, and Recreation*	†	5216	—
Finance and Insurance*	†	15,638	—
Information*	†	9076	—
Professional, Scientific, and Technical Services*	†	13,466	—
Real Estate and Rental and Leasing*	†	4720	—
Management of Companies and Enterprises		345	—
Mining, Quarrying, and Oil and Gas Extraction		946	—
Missing or Unknown Industry*	10	94,431	25.38 (16.49–36.17)

PMR, proportional mortality ratio.
*Numerator <15 and/or denominator <100 denoting rate instability.
†Counts <5 suppressed.

asbestos. Based on our evidence, future work should consider transportation workers and truck drivers as potentially at-risk groups.

Limitations

This study reflects asbestosis as captured in clinical and administrative records. Underreporting is a known and persistent limitation when it comes to asbestosis and other occupational diseases. It is also important to reiterate that our hospital and ED data set does not include federal hospitals (eg, VA hospitals). This means our assessment excludes individuals who received care only in those systems. In addition, given the lack of racial and ethnic diversity in the morbidity and mortality samples, it is possible that there is underreporting or misclassification of race and ethnicity for cases, although it is noteworthy that both samples showed this lack of diversity. Misclassification by race has been seen in other public data in Wisconsin,[46] and given the inconsistent training and education requirements for coroners and medical examiners in the state,[19] misclassification remains a possibility in our study as well. It is worth noting, however, that recent legislation passed in Wisconsin mandates consistent training for coroners and medical examiners and electronic reporting of vital records[47–49] — both of which may improve this situation for the future.

Another potential limitation is the use of usual occupation from vital records. This could limit our findings in two possible ways. First, although an individual's usual occupation may intuitively be indicative of the occupation that person held for the longest period of their life, clearly, this leaves substantial room for interpretation. It is also possible that "usual occupation" is specific to the occupation immediately preceding death, which may or may not be related to prior asbestos exposure. For instance, it is possible that some former construction or repair workers became motor vehicle operators in later life. Moreover, individuals may move into different positions within an organization as they age and their body wears out from exposure. A person indicated as having a management position on their death certificate may have started in another capacity. It is not possible from our data to determine how much asbestos exposure was due to the reported usual occupation relative to a previous occupation. Such questions are ripe for further research. Second, only occupation is asked, not industry. Thus, industry is derived from the free text information on occupation and coded into NIOCSS, which may limit its accuracy. Additionally, as mentioned previously, our analysis may be limited by use of hospital and ED discharge data, which does not include clinic-based cases. It is hoped that eCR will improve this and allow for more complete analysis of Wisconsin cases in the future. Finally, it is a limitation of this study that we are not able to see if the declines in the availability of board-certified occupational medicine physicians affected the capture of asbestosis and other pneumoconioses in the state. Future work may wish to consider these trends on a national scale.

CONCLUSIONS

Despite its known health effects, asbestos remains a potential hazard for many US workers. Our study points to an ongoing burden of excess mortality from asbestosis for individuals who worked in several occupation and industry groups. Groups at known risk, including those in Construction Occupations, those who work in specific types of Production Occupations (eg, plastics, metal), and those in Installation, Maintenance, and Repair Occupations, were also shown to be at risk. However, our analysis adds to the literature with the finding that those in Transportation and Material Moving Occupations, specifically Motor Vehicle Operators, had excess asbestosis mortality. Similarly, on the industry side, our results confirm previous findings with regard to elevated asbestosis mortality for those in Manufacturing and Construction while revealing a new relationship between asbestosis and the Transportation and Warehousing industry, specifically Truck Transportation. Our findings also highlight the potential for demographic shifts in asbestosis mortality in the future. Jobs that were historically held by White men are becoming more diverse, and this may lead to changing risks by demographics. Further, our study raises questions about the ongoing accuracy of asbestosis case capture if the availability of occupational medicine physicians continues to decline. Given that work is a social determinant of health, our study

highlights the ongoing need to monitor asbestosis and other occupational diseases and disorders through public health surveillance. Clinicians play a significant role in this process, particularly as use of eCR becomes more widespread and clinic-based diagnoses are sent to health departments. Capturing patients' occupational history when charting is invaluable to ongoing and future surveillance efforts.

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REFERENCES

1. Bang KM, Mazurek JM, Syamlal G, Wood JM. Asbestosis mortality surveillance in the United States, 1970–2004. *Int J Occup Environ Health* 2008;14:161–169.
2. Dang GT, Barros N, Higgins SA, Langley RL, Lipton D. Descriptive review of asbestosis and silicosis hospitalization trends in North Carolina, 2002–2011. *N C Med J* 2013;74:368–375.
3. Welch LS, Haile E, Dement J, Michaels D. Change in prevalence of asbestos-related disease among sheet metal workers 1986 to 2004. *Chest* 2007;131:863–869.
4. Barnes H, Glaspole I. Occupational interstitial lung diseases. *Immunol Allergy Clin North Am* 2023;43:323–339.
5. Tomasallo CD, Christensen KY, Raymond M, Creswell PD, Anderson HA, Meiman JG. An occupational legacy: malignant mesothelioma incidence and mortality in Wisconsin. *J Occup Environ Med* 2018;60:1143–1149.
6. Kurth L, Casey ML, Mazurek JM, Blackley DJ. Pneumoconiosis incidence and prevalence Among US Medicare beneficiaries, 1999–2019. *Am J Ind Med* 2023;66:831–841.
7. Simon M. Fantastically Wrong: The Legend of the Homicidal Fire-Proof Salamander. Wired. Condé Nast; 2014. August 27, 2014. Available at: https://www.wired.com/2014/08/fantastically-wrong-homicidal-salamander. Accessed March 20, 2024.
8. International Association of Heat and Frost Insulators and Allied Workers. A Mystery Worth Pondering… The Salamander in Our Union's Logo. Available at: https://www.insulators.org/salamander-story. Accessed March 20, 2024.
9. Virta RL. Worldwide Asbestos Supply and Consumption Trends from 1900 through 2003. Report. 2006:85 Circular 1298. Available at: https://pubsusgsgov/publication/cir1298. Accesssed June 24, 2024.
10. Current intellengence bulletin 62: Asbestos fibers and other elomgate mineral particles: state of the science and roadmap for research. 2011. Publication No. 2011-159. Available at: https://www.cdc.gov/niosh/docs/2011-159/pdfs/2011-159.pdf?id=10.26616/NIOSHPUB2011159. Accessed January 4, 2024.
11. EPA (Environmental Protection Agency). Biden-Harris Administration finalizes ban on ongoing uses of asbestos to protect people from cancer. Available at: https://www.epa.gov/newsreleases/biden-harris-administration-finalizes-ban-ongoing-uses-asbestos-protect-people-cancer. Accessed May 2, 2024.
12. Morris J. *The Cancer Factory: Industrial Chemicals, Corporate Deception, and the Hidden Deaths of American Workers*. Boston, MA: Beacon Press; 2024.
13. Changing patterns of pneumoconiosis mortality—United States, 1968–2000. *MMWR Morb Mortal Wkly Rep* 2004;53:627–632.
14. Bell JL, Mazurek JM. Trends in pneumoconiosis deaths — United States, 1999–2018. *MMWR Morb Mortal Wkly Rep* 2020;69:693–698.
15. Selikoff IJ, Hammond EC, Seidman H. Latency of asbestos disease among insulation workers in the United States and Canada. *Cancer* 1980;46:2736–2740.
16. Scheberle DL. *Industrial Disasters and Environmental Policy: Stories of Villains, Heroes, and the Rest of Us*. New York, NY: Taylor & Francis; 2018.
17. Environmental and Occupational Disease Case Reporting and Investigation Protocol: Asbestosis. P-02193. Wisconsin Department of Health Services; 2018. Available at: https://www.dhs.wisconsin.gov/publications/p02193.pdf. Accessed April 1, 2024.
18. Islam KM, Anderson HA. Status of work-related diseases in Wisconsin: five occupational health indicators. *WMJ* 2006;105:26–31.
19. Cotter L, Bentley T, Imm P, Creswell PD. Increased alcohol-related mortality in Wisconsin pre-COVID: a two-decade trend. *WMJ* 2022;121:269–273.
20. CDC. NIOSH Industry and occupation computerized coding system (NIOCCS). Available at: https://csams.cdc.gov/nioccs/HelpWebService.aspx. Accessed April 4, 2023.
21. U.S. Bureau of Labor Statistics. Standard Occupational Classification and Coding Structure, 2018 SOC. Available at: https://www.bls.gov/soc/2018/soc_structure_2018.pdf. Accessed July 24, 2023.
22. U.S. Bureau of Labor Statistics. Industries at a Glance: Industries by Supersector and NAICS Code. Available at: https://www.bls.gov/iag/tgs/iag_index_naics.htm. Accessed July 24, 2023.
23. American Community Survey (ACS). U.S. Census Bureau. Available at: https://www.census.gov/programs-surveys/acs/. Accessed April 4, 2023.
24. Ruggles S, Flood S, Goeken R, Schouweiler M, Sobek M. IPUMS USA: Version 12.0. IPUMS USA. Updated March 17, 2023. Available at: https://www.ipums.org/projects/ipums-usa/d010.v12.0. Accessed March 20, 2023.
25. The FREQ Procedure: Chi-Square Tests and Statistics. SAS Institute Inc. Available at: https://documentation.sas.com/doc/en/pgmsascdc/9.4_3.4/statug/statug_freq_details08.htm. Accessed April 25, 2024.
26. Billock RM, Steege AL, Minino A. COVID-19 mortality by usual occupation and industry:46 states and new York City, United States, 2020. *Natl Vital Stat Rep* 2022;71:1–33.
27. Frank J, Mustard C, Smith P, et al. Work as a social determinant of health in high-income countries: past, present, and future. *Lancet* 2023;402:1357–1367.
28. Armenti K, Sweeney MH, Lingwall C, Yang L. Work: a social determinant of health worth capturing. *Int J Environ Res Public Health* 2023;20:–1199.
29. American College of Occupational and Environmental Medicine (ACOEM). Find A Provider. Available at: https://acoem.org/acoem-find-a-provider?state=WI&boardCertifications=7. Accessed April 29, 2024.
30. Wisconsin Department of Health Services. Data and Occupational Health Publications: Indicator Data (2004–2019). Available at: https://www.dhs.wisconsin.gov/occupational-health/data.htm. Accessed April 29, 2024.
31. Council of State and Territorial Epidemiologists (CSTE). Indicator 17: Occupational Safety and Health Professionals. Available at: https://www.cste.org/page/OHIndicators#Indicator_17. Accessed Sept. 4, 2024.
32. Green-McKenzie J, Khan A, Redlich CA, Margarin AR, McKinney ZJ. The future of occupational and environmental medicine. *J Occup Environ Med* 2022;64:e857–e863.
33. Zhang Y, Rajaram N, Lau A, et al. Silicosis, asbestosis, and pulmonary fibrosis in Ontario, Canada From 1996 to 2019. *Am J Ind Med* 2023;66:670–678.
34. Rosenman KD, Trimbath L, Stanbury M. Surveillance of occupational lung disease: comparison of hospital discharge data to physician reporting. *Am J Public Health* 1990;80:1257–1258.
35. Flattery J, Woolsey C, Epstein-Corbin M, Blackley DJ, Harrison RJ, Cummings KJ. Notes From the field: surveillance of silicosis using electronic case reporting — California, December 2022–July 2023. *MMWR Morb Mortal Wkly Rep* 2023;72:1275–1276.
36. Heinzerling A, Cummings KJ, Flattery J, Weinberg JL, Materna B, Harrison R. Radiographic screening reveals high burden of silicosis among workers at an engineered stone countertop fabrication facility in California. *Am J Respir Crit Care Med* 2021;203:764–766.
37. DeBono NL, Warden H, Logar-Henderson C, et al. Incidence of mesothelioma and asbestosis by occupation in a diverse workforce. *Am J Ind Med* 2021;64:476–487.
38. Cullinan P, Muñoz X, Suojalehto H, et al. Occupational lung diseases: from old and novel exposures to effective preventive strategies. *Lancet Respir Med* 2017;5:445–455.
39. U.S. Bureau of Labor Statistics. Economy at a Glance: Wisconsin. Available at: https://www.bls.gov/eag/eag.wi.htm. Accessed May 6, 2024.
40. Paustenbach DJ, Finley BL, Lu ET, Brorby GP, Sheehan PJ. Environmental and occupational health hazards associated with the presence of asbestos in brake linings and pads (1900 to present): a "state-of-the-art" review. *J Toxicol Environ Health B Crit Rev* 2004;7:25–80.
41. Poland CA, Duffin R. The toxicology of chrysotile-containing brake debris: implications for mesothelioma. *Crit Rev Toxicol* 2019;49:11–35.
42. Cely-García MF, Sánchez M, Breysse PN, Ramos-Bonilla JP. Personal exposures to asbestos fibers during brake maintenance of passenger vehicles. *Ann Occup Hyg* 2012;56:985–999.
43. Huncharek M. Brake mechanics, asbestos, and disease risk. *Am J Forensic Med Pathol* 1990;11:236–240.
44. Teschke K, Morgan MS, Checkoway H, et al. Mesothelioma surveillance to locate sources of exposure to asbestos. *Can J Public Health* 1997;88:163–168.
45. MacArthur AC, Le ND, Fang R, Band PR. Identification of occupational cancer risk in British Columbia: a population-based case-control study of 2,998 lung cancers by histopathological subtype. *Am J Ind Med* 2009;52:221–232, 2009.
46. Creswell PD, Strickland R, Stephenson L, et al. Look local: the value of cancer surveillance and reporting by American Indian clinics. *Prev Chronic Dis* 2013;10:E197.
47. Wisconsin State Legislature. Senate Bill 173. Available at: https://docs.legis.wisconsin.gov/2023/related/proposals/sb173. Accessed April 30, 2024.
48. Wisconsin State Legislature. Senate Bill 174. Available at: https://docs.legis.wisconsin.gov/2023/related/proposals/sb174. Accessed April 30, 2024.
49. Wisconsin State Legislature. Senate Bill 176. Available at: https://docs.legis.wisconsin.gov/2023/related/proposals/sb176. Accessed April 30, 2024.

