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Diseases Attributable to Asbestos Exposure: Years of Potential Life Lost, United States, 1999–2010

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Background *Although asbestos use has been restricted in recent decades, asbestos-associated deaths continue to occur in the United States.*

Objectives *We evaluated premature mortality and loss of potentially productive years of life attributable to asbestos-associated diseases.*

Methods *Using 1999–2010 National Center for Health Statistics mortality data, we identified decedents aged ≥25 years whose death certificate listed asbestosis and malignant mesothelioma as the underlying cause of death. We computed years of potential life lost to life expectancy (YPLL) and to age 65 ($YPLL_{65}$).*

Results *During 1999–2010, a total of 427,005 YPLL and 55,184 $YPLL_{65}$ were attributed to asbestosis (56,907 YPLL and 2,167 $YPLL_{65}$), malignant mesothelioma (370,098 YPPL and 53,017 $YPLL_{65}$). Overall and disease-specific asbestos-attributable total YPLL and $YPLL_{65}$ and median YPLL and $YPLL_{65}$ per decedent did not change significantly from 1999 to 2010.*

Conclusions *The continuing occurrence of asbestos-associated diseases and their substantial premature mortality burden underscore the need for maintaining prevention efforts and for ongoing surveillance to monitor temporal trends in these diseases.* Am. J. Ind. Med. 57:38–48, 2014. *© 2013 Wiley Periodicals, Inc.*

KEY WORDS: years of potential life lost; mortality; asbestos; asbestosis; malignant mesothelioma; lung cancer

INTRODUCTION

Years of potential life lost (YPLL) is a measure of premature mortality and can be used to describe the impact on society of death from a particular illness or injury [Kamel et al., 2012]. YPLL is used to help quantify economic loss owing to premature death [Gardner and Sanborn, 1990; Pham et al., 2009] and to target prevention programs and health care planning [Perloff et al., 1984; Gardner and Sanborn, 1990]. Also, YPLL can assist in disease surveillance, and in evaluation of mortality temporal trends and program intervention effectiveness [CDC, 1986]. YPLL emphasizes deaths occurring at younger age and YPLL that occur before age 65 years measures years of potential work tenure lost, on the assumption that these are a worker's productive years [Wise et al., 1988; O'Lorcain et al., 2007].

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Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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Several diseases have been associated with exposure to asbestos fibers, including asbestosis, malignant mesothelioma, pleural plaques, and lung and other cancers [WHO, 1999; O'Reilly et al., 2007; Rudd, 2010; IARC, 2012]. Workers employed in asbestos mining and milling and those involved with manufacture, use, repair, removal, road maintenance, ship and boat building, construction, or demolition of asbestos-containing materials and products are at potential risk of exposure to asbestos [Bang et al., 2008]. Although asbestos is no longer mined in the United States, asbestos continues to be imported (approximately 1,060 metric tons in 2012) [US DI, 2013]. In 2012, the chloralkali industry consumed 67% of the imported asbestos to manufacture semipermeable diaphragms in the electrolytic cells. Thirty percent of imported asbestos was used in roofing products and the remaining 3% was used in coatings and compounds, and plastics [Virta, 2013]. Asbestos can be found in brake pads, vinyl tile, friction products, insulation, roofing materials, and other products [EPA, 2012a]. Moreover, a substantial amount of asbestos remains in buildings and eventually will be removed, either during remediation or renovations or demolition [EPA, 2012a]. It has been estimated that approximately 1.3 million workers in construction and general industry potentially are being exposed to asbestos during maintenance activities or remediation of buildings containing asbestos [Weeks and Christiani, 2005].

The U.S. Occupational Safety and Health Administration, the Mine Safety and Health Administration, and the Environmental Protection Agency have taken regulatory actions to control occupational exposure to asbestos by establishing a permissible exposure limit and banning some asbestos-containing products from the market [Martonik et al., 2001; MSHA, 2010; EPA, 2012b]. However, asbestos use has not been banned completely in the United States and asbestos-containing materials remain in place in structural materials and machinery. Non-regulated mineral fibers are causing asbestos-associated diseases as well. For example, in the United States mesothelioma was associated with commercial use of vermiculite mined in Libby, Montana [Duning et al., 2012] and asbestosis was associated with exposure to erionite which was used to pave some roads in North Dakota [Carbone et al., 2012]. Similar exposure to erionite was reported from Turkey [CDC, 2011]. Finally, estimated 41,000 persons were exposed to asbestos and other toxins during the rescue and clean-up efforts after the World Trade Center collapsed (http://www.asbestos.com/world-trade-center/). Thus, asbestos-associated deaths may continue to occur for decades to come [Nicholson et al., 1982; Antao et al., 2009; CDC, 2011].

Limited information on YPLL attributable to diseases associated with asbestos exposure is available [CDC, 2008a]. In this study, we examined YPLL attributable to mortality from asbestosis and malignant mesothelioma associated with asbestos exposure using 1999–2010 mortality data from the U.S. National Center for Health Statistics (NCHS).

MATERIALS AND METHODS

We used the 1999–2010 NCHS data because the International Classification of Disease 10th revision (ICD-10) [WHO, 1992], which assigns a separate code for malignant mesothelioma, was adopted for coding deaths in the United States beginning in 1999. The most recent year for which NCHS mortality data were available was 2010.

Using ICD-10 codes for causes of death listed in the NCHS multiple-cause-of-death data files, we identified two non-overlapping groups of decedents with diseases attributable to asbestos exposure as follows: (1) Asbestosis [J61]: pneumoconiosis due to asbestos and other mineral fibers as underlying cause of death and death with underlying cause coded as J65 (pneumoconiosis associate with tuberculosis) or J92.0 (pleural plaques with presence of asbestos) with asbestosis as a contributing cause of death and (2) Malignant Mesothelioma: mesothelioma [C45] as underlying cause of death. Because of the occupational etiology and long latency of diseases associated with asbestos exposure [Rudd, 2010], analysis was restricted to deaths of persons aged $\geq$25 years.

Statistical Analysis

We calculated YPLL to life expectancy (YPLL) and median YPLL [Wise et al., 1988] using the numbers of deaths for each race, gender, and age at death multiplied by life expectancy obtained from life tables published annually by NCHS (http://www.cdc.gov/nchs/products/life_tables.htm) and the following formula:

$$\sum_{i=25}^{100} d(j)_i e(j)_i$$

where $i =$ age; $d(j)_i =$ number of death at age i for gender or race j; j = male or female; white, black or other; $e(j)_i =$ life expectancy for gender or race j at age i. Since NCHS published age-specific life expectancy tables only for ages 0–100, the age = 100 life-expectancy estimate was used for calculating YPLLs for decedents whose age at death was greater than >100 years.

We calculated YPLL before age 65 ($YPLL_{65}$) and median $YPLL_{65}$ for decedents aged 25–64 years at death using the difference between the age of a decedent at death and 65, the upper limit of traditional working life [O'Lorcain et al., 2007] and the following formula:

$$\sum_{i=25}^{64} d_i(65 - i)$$

where $i =$ age of *i*th decedent at death; $d_i =$ number of deaths at age i.

YPLLs were internally adjusted by age, sex, and year. Since the 2009–2010 life-expectancy tables were not yet published by NCHS, the 2008 life expectancy tables were used for calculating YPLLs that occurred in 2009–2010.

We used SAS® software version 9.2 (SAS Institute, Inc., Cary, NC) nonparametric methods for data analysis. To calculate the median YPLL, PROC SUMMARY was used to calculate the 50th percentile of the YPLL distribution for demographic category (sex, race) and each state. To assess time trends we first calculated annual YPLL and $YPLL_{65}$ for each disease. Then, using a Wilcoxon signed rank test [Gibbons, 1976], we assessed the significance of time-trends based on year-to-year differences over the entire 10-year period. We used the Kruskal–Wallis test [Gibbons, 1976] to compare median YPLLs by gender and race. All tests were 2-sided and differences with $P < 0.05$ were considered statistically significant. We calculated the periodic age-adjusted YPLL rate per million per year by state using the 2000 U.S. standard population and mid-year (2005) population estimates.

RESULTS

During 1999–2010, asbestosis and malignant mesothelioma as the underlying cause of death were coded for 35,929 decedents (median age at death: 75 years), accounting for 427,005 YPLL (median per decedent: 10.0). The majority of decedents were male (29,819; 83.0%) and white (34,130; 95.0%), accounting for 345,856 (81.0%; median: 9.9) and 400,414 (93.8%; median: 9.9) YPLL, respectively (Table I). The median YPLL attributable to asbestosis and malignant mesothelioma for females (10.7) was significantly greater than that for males (9.9; $P < 0.001$). The median YPLL attributable to asbestosis and malignant mesothelioma for blacks (12.1) was significantly greater than that for whites (9.9; $P < 0.001$).

Overall, annual YPLL attributable to asbestosis and malignant mesothelioma did not change significantly (from 34,357 in 1999 to 35,818 in 2010; Table II). By state (Table III), the YPLL attributable to asbestosis and malignant mesothelioma ranged from 390 for 27 decedents in the District of Columbia (DC) to 41,384 for 3,407 decedents in California, while median asbestos-attributable YPLL per death ranged from 8.1 in North Dakota to 14.0 in DC. The age-adjusted YPLL rate per million was greatest in Maine (331). Ten states (California, Florida, Pennsylvania, Texas, New York, Illinois, Ohio, New Jersey, Michigan, and Washington) accounted for over half (52.9%) of the total YPLL attributable to asbestosis and malignant mesothelioma. These same 10 states accounted for 51.0% of total $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma.

YPLL Attributable to Asbestosis

During 1999–2010, asbestosis was coded as the underlying cause of death for 6,290 decedents (median age at death: 79 years) accounting for 56,907 YPLL (median per decedent: 8.0 YPLL). The majority of asbestosis decedents were male (6,035; 95.9%) and white (5,979; 95.1%), accounting for 54,766 (96.2%; median per decedent: 8.0) and 53,681 (94.3%; median: 8.0) YPLL, respectively (Table I). Overall, annual YPLL and median YPLL attributable to asbestosis did not change significantly over the 1999–2010 period (Table II).

YPLL Attributable to Malignant Mesothelioma

During 1999–2010, malignant mesothelioma was coded as the underlying cause of death for 29,639 decedents (median age at death: 74 years) accounting for 370,098 YPLL (median per decedent: 10.6 YPLL). The majority of mesothelioma decedents were male (23,784; 80.2%) and white (28,151; 95.0%), accounting for 291,090 (78.7%; median: 10.5) and 346,733 (93.7%; median: 10.5) YPLL, respectively. The median YPLL for other races were significantly greater than that for whites ($P < 0.001$; Table I). Overall, annual YPLL and median YPLL attributable to mesothelioma did not change significantly over the 1999–2010 period (Table II).

YPLL Before Age 65 Years ($YPLL_{65}$)

During 1999–2010, of the 35,929 deaths with asbestosis or malignant mesothelioma coded as the underlying cause of death, 6,594 (18.4%) were aged 25–64 years (median age at death: 59 years), accounting for 55,184 $YPLL_{65}$ (median per decedent: 6.0; Table IV). The majority of these decedents were male (5,051; 76.6%) and white (6,042; 91.6%), accounting for 38,882 (70.5%; median: 6.0) and 49,504 (89.7%; median: 6.0) $YPLL_{65}$, respectively. The median $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma for females was significantly greater than that for males (9.0 vs. 6.0, $P < 0.001$). The median $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma for blacks was significantly greater than that for whites (8.0 vs. 6.0, $P < 0.001$). Also, the median $YPLL_{65}$ for other races was significantly greater than that for whites ($P < 0.001$).

Overall, annual $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma did not change significantly (from 4,898 in 1999 to 3,966 in 2010; Table V). By state, the $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma ranged from 119 for 18 decedents from Delaware to 6,244 for 676 decedents from California (Table VI). The median $YPLL_{65}$ per decedent ranged from

TABLE I. Years of Potential Life Lost (YPLL) to Life Expectancy, by Sex and Race, United States, 1999–2010

	Deaths			YPLL		
Characteristics	**No.**	**%**	**Median age**	**No.**	**%**	**Median**
Asbestosis[a]						
Total	6,290	100.0	79	56,907	100.0	8.0
Sex						
Male	6,035	95.9	79	54,766	96.2	8.0*
Female	255	4.1	81	2,142	3.8	7.0
Race						
White	5,979	95.1	79	53,681	94.3	8.0
Black	262	4.2	78	2,703	4.8	8.8†
Other	49	0.7	79	524	0.9	9.0
Malignant mesothelioma[b]						
Total	29,639	100.0	74	370,098	100.0	10.6
Sex						
Male	23,784	80.2	75	291,090	78.7	10.5
Female	5,855	19.8	74	79,007	21.3	10.9*
Race						
White	28,151	95.0	75	346,733	93.7	10.5
Black	1,149	3.9	70	17,498	4.7	13.4†
Other	339	1.1	70	5,867	1.6	15.0‡
Total	35,929	100.0	75	427,005	100.0	10.0
Sex						
Male	29,819	83.0	76	345,856	81.0	9.9
Female	6,110	17.0	74	81,149	19.0	10.7*
Race						
White	34,130	95.0	76	400,414	93.8	9.9
Black	1,411	3.9	72	20,201	4.7	12.1†
Other	388	1.1	71	6,391	1.5	13.8‡

[a]ICD-10 code (underlying cause): J61 (pneumoconiosis due to asbestos and other mineral fibers) and deaths with underlying cause coded as J65 (pneumoconiosis associated with tuberculosis) or J92.0 (pleural plaques with presence of asbestos) with asbestosis as a contribution cause of death.
[b]ICD-10 code (underlying cause): C45 (mesothelioma).
*$P < 0.01$ (female vs. male).
†$P < 0.001$ (black vs. white).
‡$P < 0.001$ (other vs. white).

5.0 for decedents from Wyoming to 10.0 for decedents from the Nevada. The age-adjusted YPLL rate per million was greatest in Louisiana (53).

$YPLL_{65}$ Attributable to Asbestosis

During 1999–2010, of the 6,290 decedents with asbestosis coded as the underlying cause of death, 385 (6.1%) were aged 25–64 years (median age at death: 60 years) accounting for 2,167 $YPLL_{65}$ (median per decedent: 5.0 $YPLL_{65}$). The majority of these decedents were male (369; 95.8%) and white (341; 88.6%), accounting for 2,064 (95.2%; median: 5.0) and 1,899 (87.6%; median: 5.0) $YPLL_{65}$, respectively (Table IV). Overall, annual $YPLL_{65}$ and median $YPLL_{65}$ attributable to asbestosis did not change significantly over the 1999–2010 period (Table V).

$YPLL_{65}$ Attributable to Malignant Mesothelioma

During 1999–2010, of the 29,639 decedents with malignant mesothelioma coded as the underlying cause of death, 6,209 (20.9%) were aged 25–64 years (median age at death: 58 years) accounting for 53,017 $YPLL_{65}$ (median per decedent: 7.0 $YPLL_{65}$). The majority of these decedents were male (4,682; 75.4%) and white (5,701; 91.8%), accounting for 36,818 (69.4%; median: 6.0) and 47,605 (89.8%; median: 6.0) $YPLL_{65}$, respectively (Table IV). The median $YPLL_{65}$

TABLE II. Years of Potential Life Lost to Life Expectancy (YPLL), United States, 1999–2010

Year	Asbestosis[a] Deaths	Asbestosis[a] YPLL No.	Asbestosis[a] YPLL Median	Malignant mesothelioma[b] Deaths	Malignant mesothelioma[b] YPLL No.	Malignant mesothelioma[b] YPLL Median	Total Deaths	Total YPLL No.	Total YPLL Median
1999	452	4,366	9.0	2,342	29,991	11.1	2,794	34,357	10.6
2000	551	5,160	8.7	2,383	29,588	10.9	2,944	34,748	10.3
2001	551	5,194	8.4	2,367	29,612	10.5	2,918	34,806	9.9
2002	532	4,808	7.9	2,426	29,835	10.5	2,958	34,643	9.9
2003	585	5,411	8.0	2,473	31,016	10.6	3,058	36,427	10.0
2004	548	5,104	8.1	2,503	31,441	10.3	3,051	36,545	9.7
2005	536	4,860	7.6	2,553	31,823	10.3	3,089	36,683	9.7
2006	486	4,324	7.8	2,450	30,573	10.5	2,936	34,898	9.9
2007	540	4,785	7.9	2,429	30,478	10.6	2,969	35,263	10.0
2008	521	4,555	7.5	2,535	31,975	10.7	3,056	36,530	10.2
2009	488	4,265	7.5	2,605	32,023	10.7	3,093	36,288	10.2
2010	490	4,075	7.3	2,573	31,743	10.7	3,063	35,818	10.2

P-value for trend in deaths and YPLL for all conditions >0.05.
[a]ICD-10 code (underlying cause): J61 (pneumoconiosis due to asbestos and other mineral fibers) and deaths with underlying cause coded as J65 (pneumoconiosis associated with tuberculosis) or J92.0 (pleural plaques with presence of asbestos) with asbestosis as a contributing cause of death.
[b]ICD-10 code (underlying cause): C45 (mesothelioma).

TABLE III. Years of Potential Life Lost (YPLL) to Life Expectancy Attributable to Asbestos-Associated Diseases, by State, United States, 1999–2010

State	Deaths No.	Deaths %	YPLL No.	YPLL %	YPLL Median	YPLL Age-adjusted rate (per million per year)
Alabama	557	1.6	6,563	1.5	10.2	172
Alaska	57	0.2	679	0.2	9.6	206
Arizona	594	1.7	6,995	1.6	10.3	148
Arkansas	246	0.7	3,137	0.7	10.8	132
California	3,407	9.5	41,384	9.7	10.0	163
Colorado	377	1.0	4,784	1.1	10.7	148
Connecticut	477	1.3	5,636	1.3	9.9	192
Delaware	178	0.5	1,865	0.4	9.5	264
District of Columbia	27	0.1	390	0.1	14.0	86
Florida	2,411	6.7	27,023	6.3	9.6	155
Georgia	539	1.5	7,099	1.7	11.1	115
Hawaii	98	0.3	1,209	0.3	9.9	113
Idaho	187	0.5	2,217	0.5	10.0	205
Illinois	1,573	4.4	19,367	4.5	10.3	199
Indiana	709	2.0	8,844	2.1	10.2	178
Iowa	324	0.9	3,938	0.9	10.2	152
Kansas	267	0.7	3,109	0.7	9.6	139
Kentucky	391	1.1	5,252	1.2	11.6	154
Louisiana	677	1.9	9,008	2.1	10.9	257
Maine	350	1.0	4,005	0.9	10.0	331
Maryland	729	2.0	8,486	2.0	10.0	201

(*Continued*)

TABLE III. (*Continued.*)

State	Deaths No.	Deaths %	YPLL No.	YPLL %	YPLL Median	YPLL Age-adjusted rate (per million per year)
Massachusetts	1,093	3.0	12,309	2.9	9.4	228
Michigan	1,257	3.5	15,455	3.6	10.3	191
Minnesota	762	2.1	8,731	2.0	9.8	222
Mississippi	333	0.9	4,004	0.9	10.6	177
Missouri	574	1.6	6,968	1.6	10.5	145
Montana	212	0.6	2,307	0.5	9.5	279
Nebraska	224	0.6	2,679	0.6	10.0	189
Nevada	224	0.6	2,987	0.7	11.2	166
New Hampshire	195	0.5	2,160	0.5	9.9	209
New Jersey	1,625	4.5	17,455	4.1	9.0	244
New Mexico	171	0.5	2,313	0.5	11.1	150
New York	1,930	5.4	23,060	5.4	9.9	146
North Carolina	880	2.4	10,900	2.6	10.6	159
North Dakota	101	0.3	1,096	0.3	8.1	194
Ohio	1,584	4.4	18,726	4.4	10.2	193
Oklahoma	328	0.9	4,394	1.0	11.6	151
Oregon	630	1.8	6,946	1.6	9.1	232
Pennsylvania	2,374	6.6	25,965	6.1	9.3	226
Rhode Island	173	0.5	1,818	0.4	8.9	199
South Carolina	464	1.3	5,680	1.3	10.8	164
South Dakota	73	0.2	867	0.2	9.8	132
Tennessee	611	1.7	7,897	1.8	11.1	161
Texas	1,946	5.4	24,086	5.6	10.7	158
Utah	216	0.6	2,825	0.7	11.3	187
Vermont	73	0.2	980	0.2	11.4	181
Virginia	1,075	3.0	13,113	3.1	10.2	226
Washington	1,243	3.5	13,576	3.2	9.1	285
West Virginia	433	1.2	5,073	1.2	10.0	297
Wisconsin	860	2.4	10,513	2.5	10.6	234
Wyoming	90	0.3	1,132	0.3	11.2	272
Total	35,929	100.0	427,005	100.0	10.0	

for females was significantly greater than that for males ($P < 0.001$). The median $YPLL_{65}$ for blacks was significantly higher than that for whites ($P < 0.001$; Table IV). The median $YPLL_{65}$ for other races was significantly greater than that for whites ($P < 0.001$). Overall, annual $YPLL_{65}$ and median $YPLL_{65}$ attributable to mesothelioma did not change significantly over the 1999–2010 period (Table V).

DISCUSSION

The YPLL is an impact measure that can help quantify the burden of social and economic loss from premature mortality [Gardner and Sanborn, 1990]. The use of premature mortality measures has recently become more common for targeting cancer because it can be used to describe premature death and potential economic loss to the society caused by cancer deaths and also it can enhance the decisions of agencies for evaluating cancer prevention programs [O'Lorcain et al., 2007; Pham et al., 2009; Kamel et al., 2012]. However, information on YPLL attributable to diseases associated with asbestos exposure is limited in the United States. Adoption of the ICD-10 for coding death data with a specific code for malignant mesothelioma in 1999 and availability of data for 1999–2010 provided data to address this gap. This study is the first to report on asbestos-attributable YPLL using national mortality data.

We found that deaths attributable to asbestosis and malignant mesothelioma resulted in an annual average of 35,600 YPLL and over 4,600 $YPLL_{65}$. Nearly 96% of the total $YPLL_{65}$ attributable to asbestosis and malignant mesothelioma was due to malignant mesothelioma. No

TABLE IV. Years of Potential Life Lost Before Age 65 Years ($YPLL_{65}$) Attributable to Asbestos-Associated Diseases, by Sex and Race, United States, 1999–2010

	Deaths			$YPLL_{65}$		
Characteristics	**No.**	**%**	**Median age**	**No.**	**%**	**Median**
Asbestosis[a]						
Total	385	100.0	60	2,167	100.0	5.0
Sex						
Male	369	95.8	60	2,064	95.2	5.0
Female	16	4.2	60	103	4.8	5.5
Race						
White	341	88.6	60	1,899	87.6	5.0
Black	38	9.9	59	251	11.6	6.0
Other	6	1.5	63	17	0.8	2.5
Malignant mesothelioma[b]						
Total	6,209	100.0	58	53,017	100.0	7.0
Sex						
Male	4,682	75.4	59	36,818	69.4	6.0
Female	1,527	24.6	56	16,199	30.6	9.0*
Race						
White	5,701	91.8	59	47,605	89.8	6.0
Black	387	6.2	56	3,989	7.5	9.0†
Other	121	2.0	55	1,423	2.7	10.0‡
Total	6,594	100.0	59	55,184	100.0	6.0
Sex						
Male	5,051	76.6	59	38,882	70.5	6.0
Female	1,543	23.4	56	16,302	29.5	9.0*
Race						
White	6,042	91.6	59	49,504	89.7	6.0
Black	425	6.5	57	4,240	7.7	8.0†
Other	127	1.9	56	1,440	2.6	9.0‡

[a]ICD-10 code (underlying cause): J61 (pneumoconiosis due to asbestos and other mineral fibers) and deaths with underlying cause coded as J65 (pneumoconiosis associated with tuberculosis) or J92.0 (pleural plaques with presence of asbestos) with asbestosis as a contributing cause of death.
[b]ICD-10 code (underlying cause): C45 (mesothelioma).
*$P < 0.001$ (female vs. male).
†$P < 0.001$ (referent group: white).
‡$P < 0.001$ (referent group: white).

significant temporal trend in malignant mesothelioma attributable YPLL or $YPLL_{65}$ was observed over the years for which data were available.

Because the latency period from asbestos exposure to the development of malignant mesothelioma ranges from 20 to 50 years, most malignant mesothelioma occurs at the age of over 45 [CDC, 2008b; Maskell and Millar, 2009]. The majority (85–87%) of these cases were likely exposed to asbestos at the workplace [Rudd, 2010]. Industries with known high exposure to asbestos in the past included shipbuilding, construction, building trades, automotive brake, and the manufacture of asbestos textiles [Maskell and Millar, 2009]. Malignant mesothelioma under the age of 45 is uncommon and indicates that exposure may have occurred in younger age, likely in non-occupational settings such as exposure to naturally occurring asbestos [Pan et al., 2005].

Although most non-occupational malignant mesothelioma is likely due to asbestos exposure, exposure to other factors such as erionite, and asbestos fiber-containing vermiculite and talc have also been associated with non-occupational malignant mesothelioma [Carbone et al., 2012; CDC, 2012; Duning et al., 2012; IARC, 2012]. Erionite deposits have been documented in ten western U.S. states (California, Nevada, North Dakota, South Dakota, Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming) and exposure to erionite was associated with interstitial and pleural changes in workers with prolonged occupational

TABLE V. Years of Potential Life Lost to Age 65 Years ($YPLL_{65}$) by Year, United States, 1999–2010

Year	Asbestosis[a]			Malignant mesothelioma[b]			Total		
	Deaths	$YPLL_{65}$		Deaths	$YPLL_{65}$		Deaths	$YPLL_{65}$	
		No.	Median		No.	Median		No.	Median
1999	28	178	5.5	540	4,720	7.0	568	4,898	7.0
2000	35	215	5.0	517	4570	7.0	552	4,785	7.0
2001	39	221	6.0	520	4,689	7.0	559	4,910	7.0
2002	38	208	5.0	515	4,492	7.0	553	4,700	6.0
2003	44	284	5.0	553	4,930	7.0	597	5,214	7.0
2004	42	201	3.5	553	4,704	6.0	595	4,905	6.0
2005	38	223	5.0	566	4,626	7.0	604	4,849	6.0
2006	19	114	6.0	485	4,330	6.0	504	4,444	6.0
2007	28	129	4.0	511	4,104	6.0	539	4,233	6.0
2008	34	199	5.0	503	4,169	6.0	537	4,368	6.0
2009	24	111	3.5	491	3,801	6.0	515	3,912	6.0
2010	16	84	4.0	455	3,882	7.0	471	3,966	6.0

P-value for trend in deaths and YPLL for all conditions >0.05.
[a]ICD-10 code (underlying cause): J61 (pneumoconiosis due to asbestos and other mineral fibers) and deaths with underlying cause coded as J65 (pneumoconiosis associated with tuberculosis) or J92.0 (pleural plaques with presence of asbestos) with asbestosis as a contributing cause of death.
[b]ICD-10 code (underlying cause): C45 (mesothelioma).

TABLE VI. Years of Potential Life Lost to Age 65 Years ($YPLL_{65}$) Attributable to Asbestos-Associated Diseases, by State, United States, 1999–2010

	Deaths		$YPLL_{65}$			
	No.	%	No.	%	Median	Age-adjusted rate (per million per year)
Alabama	86	1.3	647	1.2	5.0	21
Alaska	—	—	—	—	—	—
Arizona	97	1.5	694	1.3	5.0	19
Arkansas	56	0.9	477	0.9	6.5	27
California	676	10.3	6,244	11.4	7.0	27
Colorado	81	1.2	737	1.3	6.0	23
Connecticut	89	1.4	713	1.3	6.0	29
Delaware	18	0.3	119	0.2	6.5	19
District of Columbia	—	—	—	—	—	—
Florida	362	5.5	2,817	5.1	6.0	24
Georgia	135	2.1	1,176	2.1	8.0	20
Hawaii	16	0.2	165	0.3	8.5	20
Idaho	38	0.6	278	0.5	7.0	29
Illinois	316	4.8	2,810	5.1	7.0	34
Indiana	149	2.3	1,317	2.4	7.0	33
Iowa	67	1.0	544	1.0	8.0	28
Kansas	50	0.8	429	0.8	8.0	24
Kentucky	96	1.5	869	1.6	6.0	31
Louisiana	173	2.6	1,579	2.9	8.0	53
Maine	58	0.9	394	0.7	5.0	40
Maryland	119	1.8	1,125	2.0	6.0	29
Massachusetts	188	2.9	1,528	2.8	6.5	35

(*Continued*)

TABLE VI. (*Continued.*)

	Deaths		$YPLL_{65}$			
	No.	%	No.	%	Median	Age-adjusted rate (per million per year)
Michigan	255	3.9	2,077	3.8	6.0	31
Minnesota	126	1.9	1,005	1.8	5.5	29
Mississippi	63	1.0	500	0.9	6.0	27
Missouri	100	1.5	891	1.6	8.0	23
Montana	33	0.5	234	0.4	5.0	33
Nebraska	43	0.7	377	0.7	7.0	34
Nevada	47	0.7	502	0.9	10.0	31
New Hampshire	26	0.4	219	0.4	7.5	23
New Jersey	218	3.3	1,711	3.1	6.0	28
New Mexico	47	0.7	391	0.7	8.0	31
New York	365	5.6	3,056	5.6	6.0	23
North Carolina	177	2.7	1,573	2.9	7.0	28
North Dakota	17	0.3	129	0.2	7.0	29
Ohio	297	4.5	2,133	3.9	5.0	27
Oklahoma	77	1.2	725	1.3	7.0	33
Oregon	95	1.4	827	1.5	6.0	33
Pennsylvania	339	5.2	2,513	4.6	6.0	29
Rhode Island	22	0.3	176	0.3	5.5	25
South Carolina	84	1.3	680	1.2	7.0	23
South Dakota	—	—	—	—	—	—
Tennessee	134	2.0	1,223	2.2	6.5	31
Texas	386	5.9	3,262	5.9	6.0	23
Utah	56	0.9	476	0.9	5.5	33
Vermont	21	0.3	192	0.3	7.0	44
Virginia	214	3.3	1,768	3.2	7.0	35
Washington	206	3.1	1,464	2.7	5.0	33
West Virginia	71	1.1	605	1.1	6.0	48
Wisconsin	154	2.3	1,366	2.5	7.0	36
Wyoming	21	0.3	125	0.2	5.0	32
Total	6,564	100.0	54,880	100.0	5.0	

"—" indicates fewer than 15 deaths; Data suppressed due to the National Center for Health Statistics confidentiality policy. No report due to unreliable estimate (RSE $>$ 70%).

exposure to road gravel that contains fibrous erionite [Ryan et al., 2011]. Vermiculite has been documented to increase risk for the development of malignant mesothelioma in workers that processed vermiculite mined near Libby, Montana [Duning et al., 2012]. Finkelstein [2012] recently reported that workers in the New York State talc industry were at increased risk of malignant mesothelioma attributable to their inhalation of asbestos-containing talc in the mining and milling.

Most asbestosis deaths occur among persons aged 65–84 years and overall asbestosis mortality is not expected to decrease rapidly in the next 10–15 years in the United States [Antao et al., 2009]. In our study, small numbers of deaths among persons aged 25–64 were associated with asbestosis ($n = 343$) and lung cancer *with* asbestosis or pleural plaques with presence of asbestos ($n = 200$), accounting for 4% and 2% of the total asbestos-attributable $YPLL_{65}$, respectively. A median of 5.0 $YPLL_{65}$ per decedent was attributed to asbestosis and a median of 4.0 $YPLL_{65}$ per decedent was attributed to lung cancer associated with asbestos exposure indicating that, on average, decedents aged 25–64 years with asbestosis and those with lung cancer died at age 60 and 61 years, respectively.

A small number of pleural plaques ($n = 27$) with presence of asbestosis was identified in this study. Pleural plaques are associated with exposure to asbestos [WHO, 1999]. Peretz et al. [2008] reported that "take-home" exposure to asbestos brought by family members was associated with pleural plaques among family members.

There were some differences in YPLL and $YPLL_{65}$ by gender and race. Females had a higher median YPLL attributable to malignant mesothelioma than males, and blacks had a higher median YPLL attributable to malignant mesothelioma than whites, indicating that females are dying younger than males and that blacks are dying younger than whites. Additional studies are needed to ascertain which factors (e.g., age at exposure to asbestos, access to medical care) may be associated with women's and blacks' younger age at death from malignant mesothelioma.

In this study, nearly 60% of YPLL attributable to disease associated with asbestos exposure were calculated for decedents reported from coastal states. These findings may be explained, in part, by the historical exposure to asbestos in the ship and boat building and repairing industry in coastal states [Enterline and Henderson, 1987; Bang et al., 2008]. However, no information on decedents' occupation was available to confirm these previous results.

Our method of computing YPLL to use 65 years is consistent with a study on premature mortality [Semerl and Sesok, 2002], coal workers' pneumoconiosis-related YPLL [CDC, 2009], and asbestosis-related YPLL [CDC, 2008a]. For computation of YPLL to life expectancy, we used a life expectancy tables for ages 0–100 that was published by the National Center for Health Statistics. Pham et al. [2009] used life table methods for YPLL due to cancer in Japan. The method for calculating YPLL varies among authors, depending on cut-off age or life tables of different populations. YPLL varies by different occupational diseases. Zhong and Dehong [1995] reported that mean YPLL for asbestosis and silicosis among decedents aged 15–75 years was 14.3 and 21.9, respectively.

The findings in this study are subject to some limitations. First, YPLL and $YPLL_{65}$ may be undercounted because some deaths from asbestosis and malignant mesothelioma might have been miscoded. To our knowledge, no studies addressed the magnitude of potential bias associated with coding causes of deaths according to ICD-10 coding scheme. Second, because no separate ICD-10 code is assigned to cancers associated with asbestos exposure [IARC, 2012], we were not able to calculate the total YPLL and $YPLL_{65}$ attributable to these conditions. Steenland et al. [2003] estimated annual number of lung cancer deaths associated with industrial carcinogen exposures to range 6,800–17,000, using 1997 mortality data in the United States. Although the authors have considered asbestos exposure in their calculations, no discrete estimates of lung cancer associated with asbestos were reported. Third, the disability adjusted life year (DALY) could not be estimated in this study because there is no information on years lost due to disability for diseases associated with asbestos exposure that would allow for a more accurate description of the burden of diseases attributable to asbestos exposure [WHO, 2008]. In the future, the DALY could be estimated when information on disability for these diseases is available. Fourth, the state that issues a death certificate may not be the same state in which the decedent's asbestos exposure occurred. Finally, no information on industry or occupation was available for analysis; thus, identification of specific industry and occupation associated with YPLL was not possible. The National Institute for Occupational Safety and Health has previously reported the industry and occupation information for malignant mesothelioma and asbestosis deaths from the 1999 NCHS mortality data which were included in this study [CDC, 2008b].

CONCLUSIONS

Asbestos-attributable diseases are associated with a substantial loss of potentially productive years of life. Future economic analysis might address the economic impact of asbestos-attributable diseases. The continuing occurrence of death from diseases associated with asbestos exposure underscores the need for maintaining asbestos exposure prevention and intervention efforts and for an ongoing surveillance to monitor temporal trends in these diseases.

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