

Sources and Interpretations of Asbestos Exposure Data

by

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understanding of the relationship between asbestos and cancer. Individual case studies and reviews of case series began to appear in the literature in the 1930's. However, according to Selikoff (1981) the establishment of an association in populations between occupational exposure to asbestos and lung cancer depended on the classic study of Doll (1955).

From the standpoint of cancer, there was no reason to measure exposure levels to asbestos until an association between the fibers and disease was shown. Not unexpectedly, there are few references in the literature to measured exposure levels during the 1930's, 40's, and 50's. Of course, given the long latent period for cancer, those are the exposures that are associated with today's cancer cases.

Despite the fact that asbestos was positively identified as a cause of lung cancer in the 1950's and that exposure to it was known to be widespread, no published estimate of its impact on nationwide mortality was made until 1978. In that year, two estimates were made. Selikoff (according to a footnote in the paper that is next mentioned) estimated that the annual number of asbestos-related cancer deaths was about 50,000. His estimate elicited little public attention.

The other 1978 estimate, which was titled "Estimates of the Fraction of Cancer in the United States Related to Occupational Factors," was prepared by the National Cancer Institute (NCI), the National Institute for Environmental Health Sciences (NIEHS), and the National Institute for Occupational Safety and Health (NIOSH). Ten employees of those institutes were listed as contributors to the estimates paper. Because no one was identified as the author of the paper, it is difficult to make reference to it in the usual shorthand method used for scientific publications, and it is now often called

exposed to asbestos since the beginning of World War II. Of those, 4 million were classified as "heavily exposed," and an additional 1.5 to 3.5 were classified as "significantly exposed." No details or documentation was provided for these estimates.

Thirty-five to 44 percent of the heavily exposed population were projected to die from asbestos-related cancers. This proportion of asbestos-caused cancer death was reported from a study of asbestos insulation workers by Selikoff, Hammond, and Seidman (1979; 1980). Assigning that proportion of deaths to asbestos resulted in an estimate of 1,600,000 asbestos-caused cancer deaths among the 4,000,000 heavily exposed workers (Table 1).

The significantly exposed population was projected to suffer one-quarter the asbestos-related mortality estimated for the heavily exposed workers. The estimates paper associated 400,000 to 700,000 deaths in that population with asbestos.

Thirteen to 18 percent of all cancer mortality being associated with a single substance is a frighteningly large percentage, but, at the same time, it holds great promise. It suggests that reducing asbestos exposure would significantly impact on overall cancer mortality rates.

From the standpoint of this conference, the estimates paper is especially interesting because it did not include a single estimate of the amount of asbestos that workers had been exposed to. It did depend, as does nearly every estimate that I will mention, on Selikoff and his colleagues' measurements of risks and mortality in the heavily-exposed insulation workers.

The estimates paper has been faulted because it included all exposed

striking difference between the number of workers classified as heavily exposed.

Hogan and Hoel cite a paper by Cochrane et al (1980) that reports that 17 of 92 senior staff members of a large South African asbestos/cement company had been heavily exposed to asbestos. They suggest that this 18.5 percent heavily exposed subset might be representative of the whole asbestos industry. I think that most of us would agree that extrapolating from exposure levels in a single company to estimates of exposure in a population of 7 to 8 million workers is not something to be done lightly. Hogan and Hoel apparently shared that view, and they also made a projection from data of Enterline (1978) that 3.4 percent was a best estimate for the proportion of all asbestos workers that are heavily exposed. The range around Enterline's best estimate was very wide, from 0.5 percent to something less than 25 percent, or about 50-fold. Combining estimates of 18.5 and 3.4 percent, in a way that is none too clear to me, Hogan and Hoel settled on a best estimate that 15 percent of the 7 to 8 million workers were heavily exposed. The remaining "less-heavily" exposed workers were assumed to have been exposed at one-eighth to one-quarter the rate of the heavy exposure group.

The number of workers estimated to be heavily exposed by Hogan and Hoel is between 1.06 and 1.23 million as compared to the 4.0 million from the estimates paper. This reduction by a factor of almost 4 has, of course, a pronounced effect on the the estimated number of asbestos-related cancers. Further reducing the estimate is the elimination of the 50 percent of the exposed workers who were already dead from the projections of current and future death rates. Hogan and Hoel's best estimate is that 3.1 percent of current cancer deaths are caused by asbestos with a range from 1.4 to 4.4

al's data

$$0.63 \times (7.1 - 8.2 \times 10^6) = \text{number of exposed workers} = 4.5 - 5.2 \times 10^6$$

$$(4.5 - 5.2 \times 10^6) \times (1.34 - 1.0) (0.2) = 310,000 - 350,000$$

excess cancer deaths.

The calculation from Kolonel et al's data agreed even better with Hogan and Hoel's estimate when the relative risk of 1.34 was corrected for the relative risk observed in the nonexposed shipyard workers, $rr = 0.88$. When the calculation was done on that basis, there were 470,000 to 540,000 estimated excess cancer deaths. The range of this calculation neatly brackets Hogan and Hoel's estimate of 497 thousand excess cancer deaths.

Hogan and Hoel used many of the same techniques as the estimates paper. However their best estimate for the annual asbestos-caused death rate was between 0.18 and 0.24 of the number from the estimates paper.

The Hogan and Hoel paper and the estimates paper demonstrates the absence of readily available data for estimating exposures. As is apparent from comparing the two studies, estimates of excess deaths depend on projections of the percentage of workers who were heavily exposed. There are few data available for identifying that population.

The Hogan and Hoel paper was circulated as a preprint and accepted for publication during 1980, but it was not published until a year later. During that year, a number of other papers dealing with estimates of asbestos-related cancer were presented at a Banbury House Conference at the Cold Spring Harbor Laboratory on Long Island (Peto and Schneiderman, 1981). Those papers will now be discussed.

Enterline (1981)

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Enterline's best estimate, based on three sources of data, is that 80,000 heavily-exposed workers were alive in 1981. That number, 80,000, is very much lower than the corresponding number in the estimates paper (4,000,000) and in Hogan and Hoel (about 500,000 assuming that half of the heavily exposed workers in their study were alive in 1981). Enterline borrows an estimate from Selikoff's work that heavily-exposed workers were exposed to 8-12 fiber per cubic centimeter (f/cc), as is shown on Table 1.

Enterline cites three sources of data for lung cancer death rates among workers heavily exposed to asbestos. Selikoff et al (1980) found that 22 percent of insulation workers died from lung cancer. Measurements of asbestos-caused lung cancer death rates are lower among workers in asbestos factories. Fourteen percent of retired workers from a Johns Manville plant died from asbestos-caused lung cancer (Henderson and Enterline, 1979); 15 percent in a British plant (Peto, et al, 1977). Enterline takes 20 percent as a reasonable average for death rates from asbestos-caused lung cancer and calculates that there are now 530 annual deaths from that cause among primary asbestos products workers and insulators and retirees from those trades.

Enterline applied Kolonel et al's estimate that about 60 percent of shipyard workers were exposed to asbestos and thereby reduces Hogan and Hoel's estimate of 2.5 million living persons having been exposed in World War II shipyards to 1.5 million. He also argues that exposure levels were lower in the shipyards than among the most heavily exposed workers. J. Thornton, who is not otherwise identified in Enterline's paper, is credited with making an educated guess that World War II shipyard workers were exposed at a rate about one quarter of that observed in primary asbestos workers. As is shown on the table, working through those numbers produces an annual number of 900

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mesothelioma and lung cancer, between the insulators and other workers,

(2) measured concentrations of asbestos, and

(3) the prevalence of X-ray abnormalities associated with asbestos.

In some cases, none of these measures was available, and then relative risk estimates were based on the number of mesotheliomas identified in a nationwide survey (McDonald and McDonald, 1980).

As is shown on Table 1, the projected percentages of deaths caused by asbestos were all related to the risks found for asbestos workers. Using those risk estimates and estimates of the number of people exposed (I could not easily derive those numbers from data presented in the paper), Nicholson et al calculate that the current annual number of deaths from asbestos-caused cancer is about 8,500. This number fits neatly between the 4,000 estimated by Enterline and the 12,000 by Hogan and Hoel.

It is a relatively simple matter to go through the categories of occupations in those four papers and to see where the estimates vary. The variations depend on different estimates of the numbers of workers exposed and on different estimates of exposure levels. The most remarkable thing about all the estimates may be that each depends heavily on Selikoff's estimates of asbestos-caused mortality in insulators. Almost all the other estimates are fractions of that estimate.

McDonald and McDonald (1981)

McDonald and McDonald have been leaders in collecting and analyzing data

asbestos-caused female cancer deaths is lower by an order of magnitude.

The McDonald and McDonald estimate is dependent on the percentage of mesotheliomas caused by asbestos and the ratios between asbestos-caused mesotheliomas and other cancers. They argue that the fraction of mesotheliomas caused by asbestos cannot be less than 0.5 and, of course, no greater than 1.0. Also the ratio between other cancers and mesotheliomas must lie between 1.0 and 5.0. These reasonably tight ranges produce a lower limit for their calculation of 0.5 percent of all male cancer deaths (about 1,000 annually), and an upper limit of 2.9 percent (about 6,000 annually).

J. Peto, Henderson, and Pike (1981)

This paper is a critical look at the time of appearance of mesothelioma following exposure to asbestos. The authors report that combined pleural and peritoneal mesotheliomas increase as a function of the time after first exposure raised to the 3.5 power. The appearance of mesothelioma in an exposed population is independent of age at first exposure, length of exposure, and type of asbestos fiber.

The paper presents estimates of the number of mesotheliomas to be expected in males from exposure in World War II shipyards (5,000), from other exposures during World War II (3,000), and from all exposures prior to 1965 (37,500). As is shown on Table 2, multiplying those figures by 3 and adding 37,500 mesotheliomas results in an estimate of about 150,000 cancers from all pre-1965 exposures.

The current annual number of asbestos-caused mesothelioma deaths among males is about 930. Assuming that the death rate from other asbestos-caused

cancer deaths annually because it is known to cause a few hundred mesothelioma deaths. They provide no other information about their calculations.

The agreement between the McDonald and McDonald estimate based on mesothelioma mortality and Enterline's estimate did not go unnoticed at the Banbury House Conference. I am of two minds about the agreement between the estimates. The fact that both studies project that asbestos is responsible for about 1 percent of cancer deaths can be taken as evidence that that number is, in fact, a close approximation of the true magnitude. However, I don't think more than a moment's reflection is necessary to generate a note of caution. There are a large number of assumptions in all the estimates and the congruent numbers may be partially a matter of chance. The fact that all four estimates based on mesotheliomas -- those of McDonald and McDonald, J. Peto et al, Higginson et al, and Doll and R. Peto -- are similar reflects that the same sources of data and methods of analysis were used.

Whatever reservations exist about the accuracy of the estimate that 1 percent of cancer mortality is due to asbestos, the participants at the Banbury House conference agreed that the lower estimates were more likely correct than the much higher ones reported in the estimates paper. The lower number means that we can expect a barely discernible impact on total cancer mortality as asbestos exposures decrease. Nevertheless, even 1 percent of cancer mortality represents 4,000 deaths annually. Elimination or reduction of those deaths should accompany decreasing exposures.

Exposure Assessment

The estimates of asbestos-related cancer are a clear example

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Table 1
Estimates of Cancer Mortality from Exposure to Asbestos
Based on Estimates of Numbers of Workers Exposed and Estimates of Risks

Authors	Occupational Groups	Estimated Exposure Levels	Number of Workers Exposed	Projected % of Deaths Due to Asbestos	Projected Number of Deaths	Projected Annual Deaths	% of Annual Cancer Deaths
Estimates Paper		"heavy"	4,000,000	35 to 44	1,600,000	46,000 ^a to 52,000 ^a	
		"signifi- cant"	1,500,000 to 3,500,000	35 to 44 4	400,000 to 700,000 2,000,000 to 2,300,000	12,000 ^a to 23,000 ^a 58,000 to 75,000	13-18
(estimated total number of workers exposed, 8 to 11 millions; 1 million dead at time of estimate)							
Hogan & Hoel	shipyard workers	"heavy"	640,000 to 810,000 ^a	35 to 44			
		"less heavy"	3,700,000 to 4,600,000 ^a	35 to 44 4 to 8		8,200	2.1
	others	"heavy"	150,000 ^a	35 to 44			
		"less heavy"		850,000 ^a 4 to 8	35 to 44		
	automotive	"heavy"	270,000 ^a	35 to 44			
		"less heavy"	1,530,000 ^a	35 to 44 4 to 8		4,000	1.0
					497,000	12,200	3.1 (1.4 to 4.4)
(estimated total number of workers exposed 7 to 8 million; about half alive at time of analysis.)							

a. calculated from data in paper by M.G.

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Table 2
Estimates of Cancer Mortality from Exposures to Asbestos
Estimates Based on Numbers of Mesotheliomas and a
Relationship Between that Number and the Number of Total Cancers

Authors	Basis of Calculation	Projected		% of Annual	
		Number of Deaths	Annual Deaths	Cancer Deaths	
McDonald and McDonald	8 mesotheliomas/million men X population X 0.75 = number of mesotheliomas caused by occupational exposure to asbestos: (1 + 3.3)(number of mesotheliomas) = number of all cancers caused by occupational exposure to asbestos.		(♂) 3,000 (♀) 300 (0.5 to 2.9)	(♂) 1.4 (0.5 to 2.9)	
J. Peto et al	Estimated number of mesotheliomas expected from WWII shipyards (5,000), other WWII exposures (3,000), and all pre-1965 exposures (37,500). (about 3) X (number of mesotheliomas) = number of lung cancers caused by asbestos	37,500 112,500 150,000	751 2,253 3,004		♂ 1.4
Higginson et al	(1 + 1.5)(number of mesotheliomas) + (some other cancers) = total number asbestos-caused cancers.		1,000 1,500 1,500 4,000		1.0
Doll and Peto	"since in the late 1970's some hundreds of mesotheliomas were due to asbestos, at least a few thousand other cancers must have been attributable to asbestos"		few thousand		1 or 2

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