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 were 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

the "estimates paper."

As is well known, the estimates paper was not published in a journal. Instead it was placed in the Occupational Safety and Health Administration hearing record about that agency's proposed generic cancer policy. I think it's worth wondering if the paper would have passed largely unnoticed if being deposited in the hearing record had been its only fate. However, the findings of the estimates paper were widely publicized when then-Secretary of Health, Education and Welfare Califano cited them in a speech. Based on the estimates paper, he stated that it was apparent that workplace exposures caused at least 20 percent of all cancer in this country. Asbestos alone was responsible for 13 to 18 percent.

The projections of the estimates paper were controversial as soon as they were publicized, and they attracted many attacks. They also resulted in a spate of articles that presented other estimates of the cancer risk associated with occupational exposure to asbestos.

The subsequent papers can be divided into two general groups: The first group used methods similar to the estimates paper to project numbers of cancer deaths based on estimates of numbers of workers exposed, exposure rates, and mortality rates at various exposure levels. The papers of the second kind presented measurements of the number of deaths from mesotheliomias, which are closely associated with asbestos exposure, and then multiplied that number by some factor to estimate all asbestos-caused cancer deaths.

The Estimates Paper

The estimates paper said that between 8 and 11 million workers had been

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 abestos-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

workers, even those dead at the time the estimates were made, in the projections of future deaths. It has also been criticized because it projected that there should be well over 10,000 deaths annually from mesotheliomas at the present time. The best estimate of the number of those deaths, which is based on cancer incidence data collected from about 10 percent of the United States population is almost 10 times less. Even though mesotheliomas are underreported (Selikoff, 1981), no one has suggested that the undercount is sufficient to account for the 10 fold difference.

Hogan and Hoel, 1981

The techniques used in this paper followed closely those used in the estimates paper. However, much greater detail is provided about population estimates and estimates of the number of exposed workers.

Hogan and Hoel estimate that between 7.1 and 8.2 million workers were exposed to asbestos. From data about World War II shipbuilding, they estimate that between 4.3 and 5.4 million workers were exposed to asbestos in those shipyards. The remainder of the exposed workers was estimated from data collected by NIOSH and by Research Triangle Institute. Hogan and Hoel estimate that about half of all exposed workers are now dead, significantly more than the 9 to 12 percent found in the estimates paper. Furthermore, they subtract the number of estimated dead from the total of exposed workers before estimating current and future trends. That substraction was not made in the estimates paper.

There is little difference between the total number of exposed workers in the estimates paper and in the Hogan and Hoel paper. There is, however, a

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

percent. That percentage is expected to increase slightly through the 1980's and then to decline slowly. The total number of asbestos-caused deaths is estimated at 497,000.

Hogan and Hoel made two efforts to verify their risk estimations. First, they calculated the number of deaths from mesothelioma that would be expected from their estimates of the number of workers exposed to asbestos and compared that calculated number to the number of mesothelioma deaths reported in the United States. The calculation was done by the method used for all cancers, but, in this case, including Selikoff's estimate that 6 to 10 percent of heavily exposed workers die from mesotheliomas. The calculated lower limit of about 1,000 mesothelioma deaths for 1976 falls under 1,150, which is 10 times the Surveillance, Epidemiology and End Results (SEER)-reported mesotheliomas for that year. Because the SEER program collects data on about 10 percent of the United States population, 10 times its total is a rough approximation of the total number of cases in the country. Hogan and Hoel's calculated best estimate of about 2,100 mesotheliomas is somewhat higher than, but in reasonable proximity to, the 95 percent upper confidence limit (1620 cases) of the SEER data.

The other comparison was made to data from studies done in the Pearl Harbor Naval Shipyard by Kolonel et al (1980), which reported a relative risk of 1.34 for lung cancer among shipyard workers exposed to asbestos. That paper also estimated that only 63 percent of all shipyard workers were exposed to asbestos. Using those numbers and assuming that there is an overall 20

percent risk of dying from cancer, Hogan and Hoel calculated from Kolonel et

al's data

$$0.63 \times (7.1 - 8.2 \times 106) = \text{number of exposed workers} = 4.5 - 5.2 \times 106$$

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

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)

Enterline has done a number of studies of deaths from asbestosis among asbestos industry workers. In his paper for the Banbury House Conference, he recounts the arguments that asbestosis represents a disease that occurs after long and heavy exposures. Then he summarizes the number of asbestosis deaths that have been recorded in his longitudinal studies and a study of male insulation workers by Selikoff et al (1980). Enterline finds that about half of all asbestos deaths reported in the United States occurred in those two study populations. He then calculates the size of a population of heavily-exposed workers large enough to account for all asbestosis deaths. From his own data, he estimates that the population of heavily-exposed workers alive in 1981 to be about 75,000; from Selikoff's data, about 85,000.

In a note commenting on Hogan and Hoel's (1981) paper, Nicholson (1981) states that Enterline's method for estimating the heavily exposed asbestos worker population probably underestimates the size of the population. Asbestosis develops only after a long latent period, and Nicholson argues that that disease is a poor marker for exposures more recent than 30 or more years ago.

From census data, Enterline made yet another estimate of the number of people employed in asbestos products plants and in insulation work, the most heavily exposed workers. Enterline reports that his studies show that multiplying the daily census of workers by 3 provides a reasonable estimate for the number of workers employed for at least one year in the asbestos industry over the period 1947 - 1976. Three times the daily census produced an estimate of a total of 120,000 heavily exposed workers during those 30 years. He estimates that about 90,000 were alive in 1981.

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 assumming 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. Thorton, 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

asbestos-caused lung cancer deaths among World War II shipyard workers. This number is little more than 0.1 of the Hogan and Hoel estimate, who considered the risk of cancer in shipyard workers to be the same as that seen among insulation workers.

Enterline gathers together estimates of exposure in other occupational settings, and, based on straight line extrapolation from exposure levels and years of exposure calculates the percentage of asbestos-caused lung cancer to be expected in each population. The summation of those estimates is 2,500 annually. To that number, he adds deaths from other cancers associated with asbestos exposure and comes to a total of 4,080 asbestos cancer deaths annually.

This estimate is about 0.33 of Hogan and Hoel's and only 0.06 to 0.08 of the estimates paper. In fact, it is the lowest estimate using the methods that depend on estimates of numbers of people exposed and levels of exposure.

Nicholson, Perkel, Selikoff, and Seidman (1981)

This paper estimates that the total exposed population is 13.2 million, higher than any other estimate. Of that number, 9.2 million were thought to be alive in 1981. The 13.2 million workers were segregated into 11 job categories.

The highest risk of cancer was found in insulation workers; 35 to 44 percent of those workers died from asbestos-caused cancer. The risks borne by workers in other industries were estimated by

(1) comparing directly measured mortality rates, especially for

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

about mesothelioma deaths. They have depended on data from three sources:

(1) the Third National Cancer Survey (TNCS), which was conducted in 1969 through 1971,

(2) the SEER Program of the NCI which has been ongoing since 1973, and

(3) their own efforts at complete ascertainment of mesothelomia deaths through surveys of pathologists (McDonald and McDonald, 1980). McDonald and McDonald's best estimate of the annual rates for mesothelioma deaths are 8 per million for males and 2.5 per million for females, and the rate in males is increasing.

From an examination of all cohort studies that reported both mesotheliomas and other cancers, McDonald and McDonald estimated that there are 3.3 lung cancers and 0.9 digestive cancers for every mesothelioma. To calculate the total number of cancers caused by asbestos, the number of mesotheliomas can be multiplied by 3.3, as is shown on Table 2.

The final step in the McDonald and McDonald calculation was to estimate the proportion of mesothelioma cases which was associated with occupational exposure to asbestos. Their best estimate, based on a case control study conducted by them, was 0.75 for men and less than 0.10 for women.

They calculate, based on best estimates, that there were 920 mesotheliomas among American males in 1975 and that 0.75 of that number was caused by asbestos. Based on their literature review, they estimate that there is a ratio of 3.3 asbestos-caused cancers to 1.0 mesotheliomas. That results in about 3,000 asbestos cancer deaths among males or 1.4 percent of all male cancer deaths. On the same bases, they estimate that the number of

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

cancers is about 3 times that, the total of asbestos caused cancers in males would be about 3,000 annually or 1.4 percent of total cancer mortality among males.

Higginson et al (1980)

I have not read this paper, and my brief description of it depends on a synopsis in Enterline (1981). A number of estimates place the annual mortality from mesotheliomas at about 1,000. Higginson et al reported that there are about 1.5 bronchogenic cancers related to asbestos for every mesothelioma. Multiplying 1.5 times 1,000 produces an estimate of 1,500 lung cancer cases, to those are added cancers at other sites, and Higginson et al concluded that asbestos causes about 4,000 cancer deaths annually.

Because I have not read this paper directly, I cannot comment on its quality, but it was not referenced by anyone other than Enterline at the Banbury House conference, and it may have been deficient in its presentation of details. I, for one thing, cannot understand how the total of 4,000 was reached if mesothelomia and lung cancer together were only 2,500.

Doll and R. Peto (1981)

I have a special fondness for this paper because I contracted for it when I directed the Assessment of Technologies for Determining Cancer Risks from the Environment (OTA, 1981), which was completed last summer. Doll and Peto, as is shown on the table, estimated that asbestos causes "a few thousand"

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

of strictly limited exposure data. Such limited information is likely to be the case for most exposures that occurred more than a very few years ago.

In the case of asbestos, scientists interested in extrapolating from study generated data to estimates of national cancer mortality were certainly aided by the fact that asbestos causes asbestosis and mesotheliomas. Both those diseases are reasonably rare and reasonably diagnostic for asbestos exposure. And both are subject to undercounting which limits the accuracy of estimates based on them.

In the absence of the mesothelioma data, we would now have three estimates of total asbestos cancer mortality of about 1, 2, and 3 percent of all cancers based on analysis of other available data. The Hogan and Hoel paper, the Nicholson et al paper, and the Enterline paper all followed the same general method. The different numbers they project reflect different decisions made about what numbers of workers were heavily exposed. Those decisions can be criticized because they were not made on the basis of firm information. However, that sort of information doesn't exist, and in its absence documented assumptions are the best that can be provided.

One thing that all the estimates depend on is estimates of the disease burden borne by heavily exposed asbestos workers. The work of Selikoff et al (1980) was repeatedly cited in this regard. I think that this illustrates that there will frequently be no information for making exposure estimates. In fact, we will often remain dependent on impact data from epidemiologic studies.

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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]	
		"significant"	1,500,000 to 3,500,000	35 to 44 / 4	400,000 to 700,000	12,000[a] to 23,000[a]	
					2,000,000 to 2,300,000	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 4,500,000[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.

Table 1 (continued)

Enterline	1° asbestos industry and insulation	8-12	f/cc	(living in (1981) 80,000	(lung ca.only) 20	16,000	530	
	2° asbestos industry	4	f/cc	540,000	5	27,000	900	
	WWII shipyards	2	f/cc	1,500,000	0.2	3,300	165	
	post-WWII shipyards	1	f/cc	285,000	2.7	7,695	256	
	automotive	0.3	f/cc	1,700,000	0.4	6,375	212	
	all others	0.3	f/cc	3,500,000	0.4	13,140	438	
							2,501	
					other cancers		1,250	
					mesotheliomas		330	
							4,084	1.0
				(non-occupational asbestos-caused cancers			361)	
Nicholson et al.	1° asbestos industry				35 to 44			
	2° asbestos industry				35 to 44 / 2		991	
	insulation				35 to 44		455	
	shipbuilding and repair				35 to 44 / 2		2,747	
	construction				35 to 44 / 4 to 6.6		2,423	
	RR engine repairmen				35 to 44 / 5		179	
	utility services				35 to 44 / 3.3		375	
	engineers & firemen				35 to 44 / 6.6		881	
	chemical plants				35 to 44 / 6.6		285	
	automotive				35 to 44 / 50		353	
	marine engineers				35 to 44 / 10		85	
							~~8,770~~	2.1

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 Number of Deaths	Projected Annual Deaths	% of Annual 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	(♂) 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).	37,500	751	
	(about 3) X (number of mesotheliomas) = number of lung cancers caused by asbestos	112,500 150,000	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

SOURCES AND INTERPRETATION OF ASBESTOS EXPOSURE DATA

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My talk differs from many at this meeting because it focuses on how scientists have made do with limited exposure data. It doesn't make suggestions for improvements, but it draws attention to the importance of basic epidemiologic research in learning about the impacts of exposures.

Recent years have seen increasing concern about the workplace as a source of carcinogenic exposures. To some extent, those concerns reflect the general fear of cancer, but the focus on the workplace has been sharpened by the occupational health disaster that has accompanied exposure to a single substance, asbestos.

I will review recent estimates of the amount of cancer associated with occupational exposures to asbestos. Those estimates provide examples of the sorts of situation that are certainly more common than situations characterized by good exposure data. In the case of asbestos, levels of past exposure are seldom known, the limited exposure information has not always been incorporated into assessments of risk, and slightly different guesses about exposure levels and risks associated with particular levels have produced widely varying estimates of the impact of asbestos.

Selikoff (1981) provides a short description of the development of our