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den, daß sie nicht ganz ohne Gewinn für ihre eigenen Arbeiten diese Tagung wieder verlassen werden.

Wir haben diese Tagung sozusagen in zwei Abschnitte geteilt. Der heutige Tag soll uns sagen, was die verschiedenen Forschergruppen zu den verschiedenen Themen, welche der Asbest aufwirft, als gesicherte Erkenntnis in ihren Ländern ansehen.

Der morgige Vormittag soll dann in einem Workshop-Gespräch vorwiegend unter den Referenten versuchen, das herauszustellen, was sich z. Zt. in den verschiedenen Arbeitsgruppen in der Forschung z. T. auch der Forschungsplanung befindet.

Diese zwei Tage sollen somit vor allem dazu dienen, die Effektivität unserer Arbeit anzuheben, die Arbeiten auf internationaler Ebene aufeinander abzustimmen und damit das Asbestproblem ein wenig von seinem Problematischen zu befreien.

Ich würde mich sehr freuen, wenn Sie sich an diesen Tagen hier in Berlin wohlfühlen. Heute abend gibt es den Berliner Abend im Hilton Hotel, den Sie nicht versäumen sollten. Vielleicht reicht die Zeit für den einen oder anderen, manches in dieser vom Schicksal schwer geprüften Stadt, anzusehen.

Ich hoffe, daß wir gute Arbeit leisten können und eröffne diese gemeinsame Sitzung der Sektion "Berufskrankheiten".

I. J. Selikoff, New York

## Epidemiologic Investigations of Asbestos-exposed Workers in the United States

Comparatively few studies were undertaken in the United States concerning asbestos-associated disease until the 1930s, Then, stimulated by the brillant series of British reports 1927-1929 concerning asbestos, a number of buctory surveys were undertaken 1930-1935 and showed a significant prevalence of asbestosis. At this time LYNCH nad SMITH reportet that lung cancer might also result from asbestos exposure.

Thus, by 1935, the main directions of the problem were known. Chrysotile asbestos, virtually the only fiber then used, could produce widespread disease, this disease could be fatal, and malignancy might be a result of exposure.

With this background, it is difficult to explain the curious quiet of the next 25 years. Little was done, regulations were few, and goverment inspections and supervision were infrequent. It is of interest to note that during these years when no attention was paid to this problem, 1935-1960, the use of asbestos

grew approximately fivefold in a rapidly expanding industry making thousands of products, and that approximately one million men and women in the United States began work for shroter or longer periods, often largely unprotected. Many of the cases of asbestos disease now being seen in the United States had their origin in uncontrolled excessive exposures during this time.

Towards the end of this "silent era" disquiet appeared, regarding the question of asbestos-induced cancer. Asbestos disease in the United States began to attract much more attention. A number of studies identified two major problems, which we have not solved and with which we are now concerned.

First and perhaps more important, it soon became evident that asbestosis was not the principal hazard of exposure to the fiber, but that the chief difficulty was cancer, both in the factory production of asbestos products and among workers using these materials.

In our experience, approcimately 40% of deaths among asbestos insulation workers in recent jears have been due to malignancy. We followed a cohort of 632 asbestos insulation workers in the New York metropolitan area from January 1, 1943 - December 31, 1974; they continue under observation. Altogether 305 deaths were expected. Four hundred and fifty-one occurred. The excess was lergely due to cancer. Fifty-two deaths were expected 200 occurred. Analysis of the cancer deaths by site indicated that 12 lung cancer deaths were likely to have occurred; 89 were found. Some two or three times as many cancers of the esophagus, stomach, colon and rectum occured than were expected. And there were 35 deaths from mesothelioma, 10 pleural and 25 peritoneal. Of course, no deaths of this rare disease were expected (Table 1).

Similar findings have been obtained in other groups studied. In one, we have been following all members of the Insulation Workers' Union in the United States and Canada. On January 1, 1967 there were 17,800 such men. By the end of 1973, more than 1500 deaths had occurred. Again there were approximately three times as many cancers as expected (Table 2). And again, lung cancer, mesothelioma and gastrointestinal cancer were the principal categories of such the excessive neoplastic deaths. Sixty-seven deaths from lung cancer were anticipated; 321 occured. There were 103 deaths of mesothelioma (again, with a preponderance of peritoneal sites of origin) and a modest increase of cancer of the esophagus, stomach, colon, and rectum.

We have considered the possibility that the complex environment in which these insulation workers are employed (industrial construction) might in some way be associated with their increased cancer risk. This has led us to investigate the work force of two factories making insulation materials, exposed to asbestos but not to many of the other materials found at construction worksites. The first was a plant which made amosite asbestos insulation materials. From June, 1941, to the end of 1945, 953 men began work at the plant. Some worked for as little as 1 day, others for 1 or more months and a number for somewhat over 13 years, until the plant ceased operations in November 1954. We

Table 1. Expected and observed deaths among 632 N.Y.-N.J. asbestos insulation workers, January 1, 1943-December 31, 1974

| | Expected[a] | Observed |
|---|---|---|
| Total deaths, all causes | 305.20 | 451 |
| Total cancer - all sites | 52.02 | 200 |
| Lung cancer | 12.20 | 89 |
| Pleural mesothelioma | b | 10 |
| Peritoneal mesothelioma | b | 25 |
| Cancer of stomach, esophagus | 6.46 | 20 |
| Cancer of colon | 7,64 | 23 |
| Asbestoses | b | 37 |
| All other causes | 253.18 | 214 |

[a]Six hundred and thirty two members were on the union's rolls on January 1, 1943. Nine died before reaching 20 years from first employment. All others entered these calculations upon reaching the 20-year from onset of first exposure point. Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics from 1947-72. Rates were extrapolated 1943-48 from rates for 1949-55, and for 1954 from rates for 1969-1973.

U.S. death rates not available, but these are rare causes of death in the general population.

Table 2. Expected and observed deaths among 17,800 asbestos insulation workers in the U.S. and Canada, January 1, 1967 Dezember 31, 1973

| | Expected deaths a | Observed deaths | Ratio |
|---|---|---|---|
| Total deaths | 1131.11 | 1577 | 1.39 |
| Total cancer - all sites | 209.27 | 658 | 3.14 |
| Lung cancer | 66,99 | 321 | 4.79 |
| Pleural mesothelioma | b | 36 | -- |
| Peritoneal mesothelioma | b | 67 | -- |
| Cancer of stomach | 9.82 | 16 | 1.63 |
| Cancer of colon, rectum | 24.55 | 39 | 1.59 |
| Cancer of esophagus | 4.60 | 14 | 3.04 |
| All other cancer | 103.31 | 165 | 1.60 |
| Asbestosis | b | 119 | |
| All other causes | 921.84 | 800 | 0.87 |

[a]Expected deaths are based upon age-specific white male death rate data of the U.S. National Office of Vital Statistics from 1967-1973

[b] U. S. death rates not available, but these are rare causes of death in the general population.

Table 3. Deaths among 933 workers employed in an amosite asbestos factory, starting 5 years from onset of work 1941-1945 to December 31, 1974

| Cause of death | Deaths 1946-1974 Expected[a] | Observed | Ratio |
|---|---|---|---|
| All causes | 285.62 | 483 | 1.69 |
| Cancer - all sites | 50.10 | 157 | 3.13 |
| Lung cancer | 12.45 | 83 | 6.67 |
| G.I. cancer | 12.05 | 24 | 1.99 |
| Pleural mesothelioma | b | 5 | -- |
| Peritoneal mesothelioma | b | 5 | -- |
| "Asbestos" cancer | 24.50 | 117 | 4.78 |
| Other cancer | 25.60 | 40 | 1.56 |
| Asbestosis | b | 28 | -- |
| All other causes | 235.52 | 298 | 1.27 |

[a]Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistica, 1949-1973. Rates were extrapolated for 1946-1948 from rates for 1949-1955 and for 1974 from rates for 1969-1973.

One hundred and twenty-eight workers were omitted, from these calculations: thirty-three had prior asbestos exposure; thirty-eight died in the first 5 years after onset of employment. Forty-nine were not completely traced; and eight had other asbestos employment after the 5 year from onset point.

[b] U.S. death rates not available but these are rare causes of death in the general population.

have traced this group of workers to December 31, 1974. Table 3 includes the mortality experience of these workers, starting 5 years from onset of their work. It should be noted that their experience was very much like that of the construction workers who used the products made in this factory. Again, there was a threefold increase of cancer of all sites (50 anticipated, 157 observed). Lung cancer, gastrointestinal cancer, and mesothelioma were also the major categories where excessive neoplastic deaths occurred.

In an epidemiologic investigation of workers in another asbestos factory (the largest in the United States), we are following the 611 male production employees in this factory who had begun work before January 1, 1939, and were still there January 1, 1959. By December 31, 1973, 213 were dead. Again cancer proved to be the major asbestos hazard (Table 4).

A second major difficulty now with us is derived from the appreciation that it may take much less asbestos to cause cancer than to result in asbestosis - sometimes, very little indeed. We are thus concerned not only with asbestos workers, but with the widespread dissemination of asbestos from the primary work site, exposing both other workers nearby as well as individuals not

Table 4. Expected and observed deaths among 611 New Jersey male asbestos factory employees January 1, 1959-December 31, 1973[a]

| Number of men | 611 | | |
|---|---|---|---|
| Person-years of observation | 7795 | | |
| | Expected | Observed | Ratio |
| Total deaths, all causes | 151.53 | 213 | 1.41 |
| Total cancer, all sites | 30.87 | 77 | 2.49 |
| Lung cancer | 10.16 | 30 | 2.95 |
| Pleural mesothelioma | b | 10 | -- |
| Peritoneal mesothelioma | b | 8 | -- |
| Gastrointestinal | 6.25 | 11 | 1.76 |
| Other cancer | 14.46 | 18 | 1.24 |
| Asbestosis | b | 23 | -- |
| All other causes | 120.66 | 113 | 0.94 |

a All these men began employment before January 1, 1939 and were still employed January 1, 1959.

b U.S. rates not available, but these are rare causes of death in the general population.

c Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistica, 1959-1973.

associated with the work at all. Household contamination occurs from dust brought home by workers and there ist asbestos air pollution from asbestos-using facilities, contaminating surrounding neighborhoods and, to a lesser extent, the general environment.

## Current United States Approaches to Asbestos Disease

Perspectives which provide a background to approaches designed to control or eliminate asbestos disease in the United States are largely derived from epidemiologic experiences such as those above.

1. Asbestos-associated cancer of primary concern. Control measures are now based on the realization that it is necessary to prevent asbestos-associated cancer, as well as asbestosis. In general, this implies that permissible asbestos concentrations need be significantly lower than those calculated to minimize the risk of asbestosis alone.

2. Long period of clinical latency. In evaluating efficacy of measures designed to prevent cancer, it is appreciated that the long period of clinical latency of asbestos cancer must be taken into account. Our studies and those of others have demonstrated that cancers associated with asbestos exposure often do not become clinically evident for 20 or more years after onset of exposure. Frequently, the elapsed period is 30, 40 or more years.

3. Brief (excessive) exposure may produce later disease. Even brief exposure - a day, a week, a month - if excessive, can later result in disease. The inhaled fibers remain in the lung. Thus, the men employed in the amosite asbestos products factory mentioned above, 1941-1945, worked for varying periods of time. Approximately one-third worked for 3 months or less, one-third-for 3 - 1 months and one-third for a year or more. Even less than 3 months of work resulted, during the next 30 or so years, in significantly increased cancer risk (Table 5). Nevertheless, those with longer periods of work were at an even greater risk.

4. Dose-response relationship. There is little doubt that a dose-response relationship exists for several asbestos-associated diseases. This is - well demonstrated by the experience of the amosite asbestos factory workers referred to above. Here, workers were exposed to the same fiber, during the same period of time, making the same products, in the same city; they varied, however, with regard to their total exposure.

The Table 6a and b indicates that the risk of death of lung cancer, for example, increased steadily with increassed exposure, taking into account equivalent lapsed periods from onset of exposure.

An unanswered question, related to the problem of "dose-disease response" relationship is whether or not a "safe" exposure exists. From a practical point of view one might consider that observations of a continous reduction in identifiable cancer risk with decrease in levels of exposure suggest that it may be feasible to reach levels at which it will not be possible to statistically define increased risk of cancer of those sites known to be associated with a neoplastic effect of asbestos.

5. Unresolved questions. Epidemiologic studies are also being undertaken in a number of areas in which data are still inadequate for evaluation of health effects. These include:

a) Industry efforts to control exposures. In recent years there has been a sharp increase in the scope and intensity of industry approaches to control exposures. Evidence is being sought concerning the effectiveness of these efforts.

b) End product use. Still unresolved is the control of exposures encountered in the use of asbestos products. This is not only true construction industry, shipyards, and power plants, but in such uses as brake repair and brake maintenance.

c) Demolition, waste disposal, maintenance, and repair. As with end product use, waste disposal, demolition of asbestos-containing structures, and the necessity for repair of facilities containing asbestos materials are thorny probleme. So far, little research has been devoted to the question of health effects associated with such work.

d) Other factors which may influence risk. It may be that risk also varies with other factors, such as intensity of exposure, peak exposures, type of fiber, individual susceptibility, etc.

Table 5. Expected and observed deaths subsequent to first year after onset of employment among 870 amosite asbestos factory workers first employed 1941-45 and observed to December 31, 1973. Distribution of duration of employment

| | 3 months work or less | | | 3-11 months work | | | 1 year + work | | |
|---|---|---|---|---|---|---|---|---|---|
| | Expected | Observ. | Ratio | Expected | Observ. | Ratio | Expected | Observ. | Ratio |
| Total deaths, all causes | 99.75 | 112 | 1.12 | 94.34 | 170 | 1.80 | 110.55 | 216 | 1.95 |
| Cancer - all sites | 16.92 | 28 | 1.65 | 16.29 | 46 | 2.82 | 18.99 | 81 | 4.27 |
| Lung cancer | 4.13 | 16 | 3.87 | 4.00 | 16 | 4.00 | 4.64 | 49 | 10.56 |
| Pleural mesothelioma | n.a.a | 0 | -- | n.a. | 2 | -- | -- | n.a. | -- |
| Peritoneal mesothelioma | n.a. | 0 | -- | n.a. | 1 | -- | n.a. | 4 | -- |
| Cancer stomach | 1.46 | 1 | 0.68 | 1,47 | 3 | 2.04 | 1.73 | 5 | 2.89 |
| Cancer colon, rectum | 2.38 | 4 | 1.68 | 2.27 | 7 | 3.08 | 2.67 | 5 | 1.87 |
| Asbestoses | n.a. | 1 | -- | n.a. | 2 | -- | n.a. | 23 | -- |
| All other causes | 82.83 | 82 | 1.00 | 78.05 | 122 | 1.56 | 91.56 | 112 | 1.22 |
| Number of workers | | 249 | | | 294 | | | 327 | |
| Person-years of observation | | 5747 | | | 6305 | | | 7061 | |

This table excluded 63 men. Ten died during first year of employment, 34 could not be traced after the first year, and 19 had prior occupational exposure to asbestos. Of the 870 men, 18 were partially traced and 16 had subsequent asbestos work. These remained in the calculations until lost to observation or until onset of subsequent asbestos work. Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics, 1949-71. Rates were extrapolated for 1941-48 from rates for 1949-55, and for 1972-73 from rates for 1967-71.

a U.S. death rates not available but these are rare causes of death in general population.

Table 6a. Deaths of lung cancer among 933 workers employed in an amosite asbestos factory, starting 5 years from onset of work 1941-1945 to December 31, 1974. Effect of duration of exposure

| Duration of employment | No. | Death of Lung Cancer 1946-1974 Expected[a] | Observed | Ratio |
|---|---|---|---|---|
| 1 month | 62 | 1.34 | 3 | 2.24 |
| 1 month | 92 | 1.44 | 5 | 3.47 |
| 2 months | 79 | 1.30 | 8 | 6.15 |
| 3-5 months | 145 | 2.24 | 8 | 3.57 |
| 6-11 months | 129 | 1.63 | 9 | 5.52 |
| 1 year | 105 | 1.53 | 12 | 7.84 |
| 2 years | 77 | 1.06 | 13 | 12.26 |
| 3-4 years | 51 | 0.87 | 9 | 10.34 |
| 5 years | 65 | 1.04 | 16 | 15.36 |
| Total | 805 | 12.45 | 83 | 6.67 |

[a] Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics. 1949-1973. Rates were extrapolated for 1946-1948 from rates for 1949-1955 an for 1974 from rates for 1969-1973.

One hundred and twenty-eight workers were omitted from these calculations: thirty-three had prior asbestos exposure; thirty eight died in the first 5 years after onset of employment. Forty-nine were not completely traced; and eigth had other asbestos employment, after the 5 year from onset point.

Table 6b. Deaths of lung cancer among 933 workers employed in an amosite factory, starting 5 years from onset of work 1941-1945 to December 31, 1974. Effect of duration from onset of esposure

| Years from onset of exposure | Number alive start of period | Deaths of lung cancer 1946-1974 Expect.[a] | Observ. | Ratio |
|---|---|---|---|---|
| 5 - 9 | 805 | 1.24 | 2 | 1.61 |
| 10 - 14 | 754 | 1.79 | 12 | 6.70 |
| 15 - 19 | 680 | 2.12 | 20 | 9.40 |
| 20 - 24 | 579 | 2.90 | 18 | 6.21 |
| 25 - 29 | 469 | 3.14 | 23 | 7.32 |
| 30 - 32 | 361 | 1.25 | 8 | 6.40 |
| Total | 805 | 12.45 | 83 | 6.67 |

[a] Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics, 1949-1973. Rates were extrapolated for 1946-1948 from rates for 1949-1955 and for 1974 from rates for 1969-1973.

One hundred and twenty-eight workers were omitted from these calculations: thirty-three had prior asbestos exposure; thirty-eight died in the first 5 years after onset of employment. Forty-nine were not completely traced; and eight had other asbestos employment after the 5 year from onset point.

## Conclusion

Asbestos disease and asbestos-associated deaths that have recently been seen in the United States are largely related to the inadequately controlled use of asbestos 1930-1940, when some 150,000 - 300,000 tons per year were used in the United States. At present, approximately 850.000 tons per annum are used (Table 7). It is sobering to consider that, to the extent that this use was inadequately controlled, we will see deaths of asbestosis and cancer in the year 2000.

Table 7. U.S. consumption of asbestos

| | Tons |
|---|---|
| 1930 | 120,000 |
| 1940 | 262,000 |
| 1950 | 727,000 |
| 1960 | 710,000 |
| 1973 | 862,000[a] |

[a] Chrysotile 839,200 tons, amosite 4,273 tons, crocidolite 17,966 tons, and anthophyllite 1,162 tons. (Source U.S. Bureau of Mines)

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