

## Mortality and cancer incidence in the man-made mineral fiber industry in Sweden

by Peter Westerholm, MD,<sup>1</sup> Anne-Marie Bolander, MD (hc)<sup>2</sup>

WESTERHOLM P, BOLANDER A-M. Mortality and cancer incidence in the man-made mineral fiber industry in Sweden. *Scand J Work Environ Health* 12 (1986): suppl 1, 78–84. This report gives an account of the Swedish contribution to the joint European epidemiologic study on production workers in the man-made mineral fiber (MMMF) industry. The information sources utilized and the follow-up procedure, making extensive use of record-linkage operations extracting data from computerized data banks, are described in some detail. The follow-up with regard to vital status, deaths and causes of death, diagnosed cancers, and emigration could essentially be based on such techniques. The problems of tracing immigrant and emigrant subpopulations are given particular attention. The exposed Swedish cohort consisted of 3 600 persons giving 61 690 person-years of observation. A total of 524 deaths was observed in the cohort, 230 cohort members had emigrated during the period of observation (147 of whom could be traced to other Nordic countries), and 62 other persons were lost to follow-up. It was observed that most of the persons contracting lung cancer in the Swedish cohort had been exposed during relatively short periods of time, ie, during one to four years of employment. This finding applied to both the rock-wool and glass-wool industry. The authors point out that the observed excess risk in lung cancer deaths may also have other explanations than occupational exposure to MMMF.

*Key terms:* migrants, national versus regional reference rates, record-linkage follow-up.

The Swedish contribution to the joint European epidemiologic study (3) consists of information obtained from the following three factories: Gullfiber AB Billeholm (glass-wool production), Rockwool AB (slag- and rock-wool production), and Laxå Bruk (slag- and rock-wool production).

At Rockwool AB in Skövde the production started in 1938. Over the years the company engaged a successively increasing number of workers. At this factory slag was initially used, but only after a few years it was replaced by rock (diabase) as the raw material for fiber production. At Laxå Bruk fiber production started in 1943 as a new type of production, being added to the existing iron manufacturing which had been the main production line for about 300 years. At Gullfiber AB in Billeholm the production started in 1933, glass fibers being the product from the outset.

### Identification of the cohort

The study cohort of persons exposed to mineral fibers in the factories was identified through scrutiny of all available personnel records going back to the start of production. For the best possible ascertainment of record completeness, we were assisted by working groups at each factory. These groups consisted of representatives of the employer, the factory trade

unions, and also former employees with good knowledge and recollection of work conditions.

The information extracted from the records included identification data such as name and a nine- or ten-digit identity number (the Swedish personal identification number, introduced in 1947) or, for part of the cohort, only date of birth (making the follow-up procedures rather complicated), and details of the work performed (including period of employment and job category at the factory). The data on occupation were classified and coded in the format applied to the whole European cohort. A minimum of one year of employment in a job entailing exposure to man-made mineral fibers (MMMF) was set as a requirement for entry into the cohort.

### Follow-up procedures

Individual identity, ie, the personal identification numbers, was checked and added to the information retrieved from the personnel records. Persons lacking adequate identification numbers were dealt with separately, until they had been traced and information on them had been completed. All the data formed a register, transferred to magnetic tape and used as the basic source of information in the follow-up operations carried out through matching procedures and record linkage. The registered cohort was matched with centrally stored, computerized data bases containing information on the total population, those alive at different points in time, deaths, cancer incidence, and emigration.

<sup>1</sup> The Swedish Trade Union Confederation, Stockholm, Sweden.

<sup>2</sup> Statistics Sweden, S-115 81 Stockholm, Sweden.

Reprint requests to: Dr P Westerholm, The Swedish Trade Union Confederation, S-105 53 Stockholm, Sweden.

The sources of information used to establish follow-up status were registers of the total population of Sweden of 31 December 1982 and of 31 December 1978 and registers on vital events at Statistics Sweden in Örebro.

Through record linkage, the cohort was matched with the register of the total population of 1982. Since both names and personal identification numbers were used for identification in the matching of persons, the cohort members alive at the end of the follow-up period could be properly identified.

The members of the cohort not ascertained to be alive on 31 December 1982 were then matched with the register of the total population of 1978. As a result of this procedure persons alive on 31 December 1978 could be identified. The remainder of the cohort then consisted of persons who had died before December 1978, had emigrated some time during the observation period, or were lost in some other way.

The deaths were traced in the cause-of-death registers of 1952–1960 and of 1961–1982, kept by Statistics Sweden. This source comprises information on all the persons in the Swedish population who have died during the two periods.

The deaths in the study cohort were identified through matching with these registers, and their records were extracted, giving date and causes of death according to the code of the International Classification of Diseases (ICD) valid at that time. The emigrants were searched for in the emigrant registers of 1960–1967 and of 1968–1982, set up and kept by Statistics Sweden and containing information on nationality, country of birth, date and country of emigration, marital status, etc.

Those members of the cohort who had emigrated since they left the factory could, by computerized information sources, only be traced in the emigrant registers from 1960 and on. Other possible emigrants were checked in the manual person register, kept by the National Board of Taxation and Civil Registration, containing persons having emigrated, immigrated, or changed personal identification number since 1948. Their records gave the date and country of emigration, ie, all the information needed for the further tracing.

The follow-up also included cancer incidence, the incident cases being traced in the Swedish Cancer Register, set up in 1958 and maintained by the National Board of Health and Welfare. This computer-based register contains information on all new cases of malignant neoplasms from 1958 on. Notification of diagnosed cancer cases is compulsory according to the Swedish Code of Statutes, both for clinicians and pathologists, which thus leads to a double reporting of each case. The records contain the personal identification number and name in addition to the information on diagnosis as to site and histology according to the seventh revision of the ICD and a special histology code. They also give date of notification. In the follow-up these data were used as end-points by them-

selves and as control of the possible cause-of-death diagnosis.

## Immigrant populations

Part of the cohort consisted of immigrants of foreign or Swedish nationality. They constituted a group for which different administrative routines are and have been applied with regard to civil registration. This fact obviously leads to difficulties in epidemiologic follow-up studies and therefore deserves a special comment.

Immigrants into Sweden are always given a personal identification number by the National Board of Taxation and Civil Registration when they are entered into a parish register. Formerly the three registration digits of the personal identification number for immigrants were chosen in the range of 932 to 999, making them easy to identify and trace. This procedure was regarded, however, as an act of discrimination, and they now get any free number in the series for their day of birth. Therefore it is now more difficult to find and identify them. Not all foreigners entering Sweden get the status of immigrant at once, especially not as long as they are registered as residents in their former country. For taxation purposes, however, they are given a temporary number, never recorded in the parish or county registers, and they can be traced in a special taxation register at the National Board of Taxation, but they never appear in the registers of vital events as deceased or emigrated, or in the Cancer Register. Therefore they have to be excluded from the study cohort. As "guest workers" they may be employed for less than a year at a time without being registered. Generally such persons stay for several short periods as prolonged holidays away from their home country. It is also possible to belong to the Swedish cohort and to live and to be registered in a neighboring country, for example, as a daily commuter, mainly between Denmark and Sweden.

It has been possible to trace those workers in our cohort who have emigrated to another Nordic country in the Danish, Finnish and Norwegian population registers. In this manner the number of losses to follow-up have been decreased by more than a hundred cohort members.

Causes of death and cancer diagnoses were reported directly to the International Agency for Research on Cancer in Lyon by cohort number identification in order to satisfy legal requirements for the protection of anonymity of cohort members.

## Completeness of the follow-up

The sources of information mentioned made it possible to ascertain the follow-up status of the 3 600 persons in the exposed cohort. A total of 524 deaths had occurred, and 230 persons (6.4 %) had emigrated, of whom 147 persons could be traced in the Nordic coun-

tries. Since these Nordic migrants were successfully traced, we chose not to regard them as lost. Sixty-two persons were otherwise lost to follow-up (table 1).

## Results

The overall mortality in some broad categories of causes of death in the Swedish cohort is shown by type of production in table 2. The information under the heading rock wool/slag wool shows the combined data relating to the cohorts from Rockwool AB in Skövde and Laxå Bruk AB.

Table 3 shows the follow-up results in the rock-wool/slag-wool factories regarding deaths from can-

cer of the trachea, bronchus, and lung. The cohort was divided into subgroups according to time of exposure (years of employment) and length of observation, defined as time elapsed from the first exposure to the

**Table 2.** Observed (O) number of deaths, expected (E) number of deaths based on national death rates, and the standardized mortality ratio (SMR) for the Swedish cohort by selected causes of death and type of production.

| Cause of death <sup>a</sup>                     | O   | E     | SMR |
|-------------------------------------------------|-----|-------|-----|
| All causes (000—999)                            |     |       |     |
| Rock wool/slag wool                             | 203 | 217.0 | 94  |
| Glass wool                                      | 281 | 304.6 | 92  |
| All malignant neoplasms (140—209)               |     |       |     |
| Rock wool/slag wool                             | 38  | 48.3  | 79  |
| Glass wool                                      | 71  | 70.1  | 101 |
| Cancers of the trachea, bronchus and lung (162) |     |       |     |
| Rock wool/slag wool                             | 8   | 7.6   | 105 |
| Glass wool                                      | 10  | 8.8   | 114 |
| Nonmalignant respiratory disease (460—519)      |     |       |     |
| Rock wool/slag wool                             | 7   | 9.9   | 71  |
| Glass wool                                      | 13  | 15.1  | 86  |
| Accidents, poisonings and violence (E800—E999)  |     |       |     |
| Rock wool/slag wool                             | 35  | 25.7  | 136 |
| Glass wool                                      | 34  | 28.0  | 121 |

<sup>a</sup> Code of the International Classification of Diseases, eighth revision, in parentheses.

**Table 1.** Characteristics of the Swedish cohort according to type of production.

|                          | Rock wool/slag wool | Glass wool |
|--------------------------|---------------------|------------|
| Exposed cohort           | 1 578               | 2 022      |
| Men                      | 1 403               | 1 480      |
| Women                    | 175                 | 542        |
| Number lost to follow-up | 15                  | 47         |
| Emigrated                | 76                  | 154        |
| Person-years observed    | 26 996              | 34 693     |

**Table 3.** Mortality from cancer of the trachea, bronchus, and lung<sup>a</sup> by length of employment and length of follow-up in the rock-wool/slag-wool production subcohort. (O = observed number of deaths, E = expected number of deaths based on national death rates, SMR = standardized mortality ratio)

| Length of employment (years) | Years since first exposure |     |     |       |     |     |       |     |     |     |     |     |       |     |     |
|------------------------------|----------------------------|-----|-----|-------|-----|-----|-------|-----|-----|-----|-----|-----|-------|-----|-----|
|                              | ≤9                         |     |     | 10—19 |     |     | 20—29 |     |     | ≥30 |     |     | Total |     |     |
|                              | O                          | E   | SMR | O     | E   | SMR | O     | E   | SMR | O   | E   | SMR | O     | E   | SMR |
| 1—4                          | —                          | 0.8 | 0   | 2     | 1.0 | 200 | 1     | 1.0 | 102 | 4   | 0.5 | 888 | 7     | 3.3 | 215 |
| 5—9                          | —                          | 0.5 | 0   | —     | 0.5 | 0   | —     | 0.2 | 0   | —   | 0.2 | 0   | —     | 1.4 | 0   |
| 10—19                        | —                          | 0   | 0   | —     | 0.8 | 0   | —     | 0.6 | 0   | —   | 0.2 | 0   | —     | 1.5 | 0   |
| ≥20                          | .                          | .   | .   | .     | .   | .   | 1     | 0.5 | 192 | —   | 0.6 | 0   | 1     | 1.1 | 87  |
| Total                        | —                          | 1.3 | 0   | 2     | 2.4 | 87  | 2     | 2.4 | 83  | 4   | 1.6 | 253 | 8     | 7.6 | 105 |

<sup>a</sup> Code of the International Classification of Diseases, eighth revision, 162.

**Table 4.** Mortality from cancer of the trachea, bronchus, and lung<sup>a</sup> by length of employment and length of follow-up in the glass-wool production subcohort. (O = observed number of deaths, E = expected number of deaths based on national death rates, SMR = standardized mortality ratio)

| Length of employment (years) | Years since first exposure |     |     |       |     |     |       |     |     |     |     |     |       |     |     |
|------------------------------|----------------------------|-----|-----|-------|-----|-----|-------|-----|-----|-----|-----|-----|-------|-----|-----|
|                              | ≤9                         |     |     | 10—19 |     |     | 20—29 |     |     | ≥30 |     |     | Total |     |     |
|                              | O                          | E   | SMR | O     | E   | SMR | O     | E   | SMR | O   | E   | SMR | O     | E   | SMR |
| 1—4                          | —                          | 1.2 | 0   | —     | 1.3 | 0   | 3     | 1.2 | 260 | 4   | 1.2 | 345 | 7     | 4.8 | 147 |
| 5—9                          | 1                          | 0.4 | 235 | —     | 0.5 | 0   | —     | 0.5 | 0   | —   | 0.5 | 0   | 1     | 1.9 | 52  |
| 10—19                        | .                          | .   | .   | 1     | 0.5 | 0   | —     | 0.4 | 0   | —   | 0.3 | 0   | 1     | 1.3 | 79  |
| ≥20                          | .                          | .   | .   | .     | .   | .   | —     | 0.2 | 0   | 1   | 0.3 | 333 | —     | 0.6 | 0   |
| Total                        | 1                          | 1.7 | 60  | 1     | 2.4 | 42  | 3     | 2.3 | 128 | 5   | 2.4 | 205 | 10    | 8.8 | 114 |

<sup>a</sup> Code of the International Classification of Diseases, eighth revision, 162.

termination of the follow-up or to death. The estimates of expected numbers were based on mortality statistics for all Sweden by sex, age, and cause of death for each calendar year.

With reference to table 3 we feel it proper to point out that the one case of lung cancer in the category  $\geq 20$  years of employment and the 20–29 years of follow-up period has not been verified to be a primary tumor of the lung. The scanty record of the perfunctory post-mortem examination did not provide satisfactory ascertainment on this point. Two expert pathologists, having reexamined the records and pathology specimens, expressed the opinion that the tumor was a metastatic lung cancer and no primary tumor of the lung. We have chosen, however, to keep this case included in the tables, as it was not possible to state the primary site with certainty; the opinions of two pathology professors should be kept in mind, however, both suggesting pancreas as site of the primary tumor.

In the slag-/rock-wool production the excess of observed deaths from cancer of the trachea, bronchus, and lung was concentrated to the group with one to four years of exposure. Corresponding results for the glass-wool production are found in table 4, where a high number of observed deaths from tumors of the respiratory system can also be found in the group with one to four years of exposure.

Table 5 shows the results of the follow-up of cancer incidence. The source of information was the Swedish Cancer Register. The results relate to the part

of the observation period during which the Cancer Register existed, ie, from the beginning of 1958 on.

For the calculation of expected numbers of cancer incidence, rates for all of Sweden were used by sex, age, cancer diagnosis, and calendar year. The relation between observed and expected numbers has been expressed as the standardized incidence ratio (SIR).

In tables 6 and 7 the follow-up data on cancer mortality — with particular regard to the cancers of the

**Table 5.** Observed (O) number of incident cancer cases, expected (E) number of cancer cases, and the standardized incidence ratio (SIR) for the Swedish cohort according to selected types of cancer and type of production.

| Type of cancer <sup>a</sup>                     | O  | E     | SMR   |
|-------------------------------------------------|----|-------|-------|
| All malignant neoplasms (140–209)               |    |       |       |
| Rock wool/slag wool                             | 66 | 78.1  | 83.9  |
| Glass wool                                      | 92 | 107.6 | 85.5  |
| Cancers of the trachea, bronchus and lung (162) |    |       |       |
| Rock wool/slag wool                             | 9  | 8.2   | 109.5 |
| Glass wool                                      | 10 | 9.0   | 110.6 |
| Cancer of the stomach (151)                     |    |       |       |
| Rock wool/slag wool                             | 9  | 6.0   | 149.5 |
| Glass wool                                      | 7  | 7.9   | 88.8  |
| Cancer of the intestine, except rectum (154)    |    |       |       |
| Rock wool/slag wool                             | 4  | 5.9   | 67.8  |
| Glass wool                                      | 4  | 8.1   | 49.6  |

<sup>a</sup> Code of the International Classification of Diseases, seventh revision, in parentheses.

**Table 6.** Mortality from cancer of the trachea, bronchus, and lung<sup>a</sup> by length of follow-up and technological phase in the rock-wool/slag-wool production subcohort. (O = observed number of deaths, E = expected number of deaths based on national death rates, SMR = standardized mortality ratio)

| Techno-<br>logical<br>phase | Years since first exposure |     |     |       |     |     |       |     |     |     |     |     |       |     |     |
|-----------------------------|----------------------------|-----|-----|-------|-----|-----|-------|-----|-----|-----|-----|-----|-------|-----|-----|
|                             | ≤9                         |     |     | 10—19 |     |     | 20—29 |     |     | ≥30 |     |     | Total |     |     |
|                             | O                          | E   | SMR | O     | E   | SMR | O     | E   | SMR | O   | E   | SMR | O     | E   | SMR |
| Early                       | —                          | 0.1 | 0   | —     | 0.3 | 0   | 1     | 0.8 | 127 | 3   | 1.3 | 227 | 4     | 2.5 | 157 |
| Middle                      | —                          | 0.0 | 0   | —     | 0.1 | 0   | —     | 0.3 | 0   | 1   | 0.2 | 625 | 1     | 0.6 | 173 |
| Late                        | —                          | 1.2 | 0   | 2     | 1.8 | 109 | 1     | 1.4 | 72  | —   | 0.1 | 0   | 3     | 4.5 | 67  |
| Total                       | —                          | 1.3 | 0   | 2     | 2.3 | 88  | 2     | 2.4 | 82  | 4   | 1.6 | 253 | 8     | 7.6 | 105 |

<sup>a</sup> Code of the International Classification of Diseases, eighth revision, 162.

**Table 7.** Mortality from cancer of the trachea, bronchus, and lung<sup>a</sup> by length of follow-up and technological phase in the glass-wool production subcohort. (O = observed number of deaths, E = expected number of deaths based on national death rates, SMR = standardized mortality ratio)

| Techno-<br>logical<br>phase | Years since first exposure |     |     |       |     |     |       |     |     |      |     |     |       |     |     |
|-----------------------------|----------------------------|-----|-----|-------|-----|-----|-------|-----|-----|------|-----|-----|-------|-----|-----|
|                             | ≤ 9                        |     |     | 10—19 |     |     | 20—29 |     |     | ≥ 30 |     |     | Total |     |     |
|                             | O                          | E   | SMR | O     | E   | SMR | O     | E   | SMR | O    | E   | SMR | O     | E   | SMR |
| Early                       | 1                          | 0.7 | 152 | 1     | 1.5 | 65  | 3     | 2.3 | 129 | 5    | 2.4 | 205 | 10    | 7.4 | 144 |
| Middle <sup>b</sup>         | —                          | 0.0 | 0   | —     | 0.0 | 0   | —     | 0.0 | 0   | —    | 0.0 | 0   | —     | 0.0 | 0   |
| Late                        | —                          | 1.0 | 0   | —     | 0.8 | 0   | —     | 0.0 | 0   | —    | 0.0 | 0   | —     | 1.8 | 0   |
| Total                       | 1                          | 1.7 | 60  | 1     | 2.4 | 42  | 3     | 2.3 | 128 | 5    | 2.4 | 205 | 10    | 8.8 | 114 |

<sup>a</sup> Code of the International Classification of Diseases, eighth revision, 162.

<sup>b</sup> Not applicable.

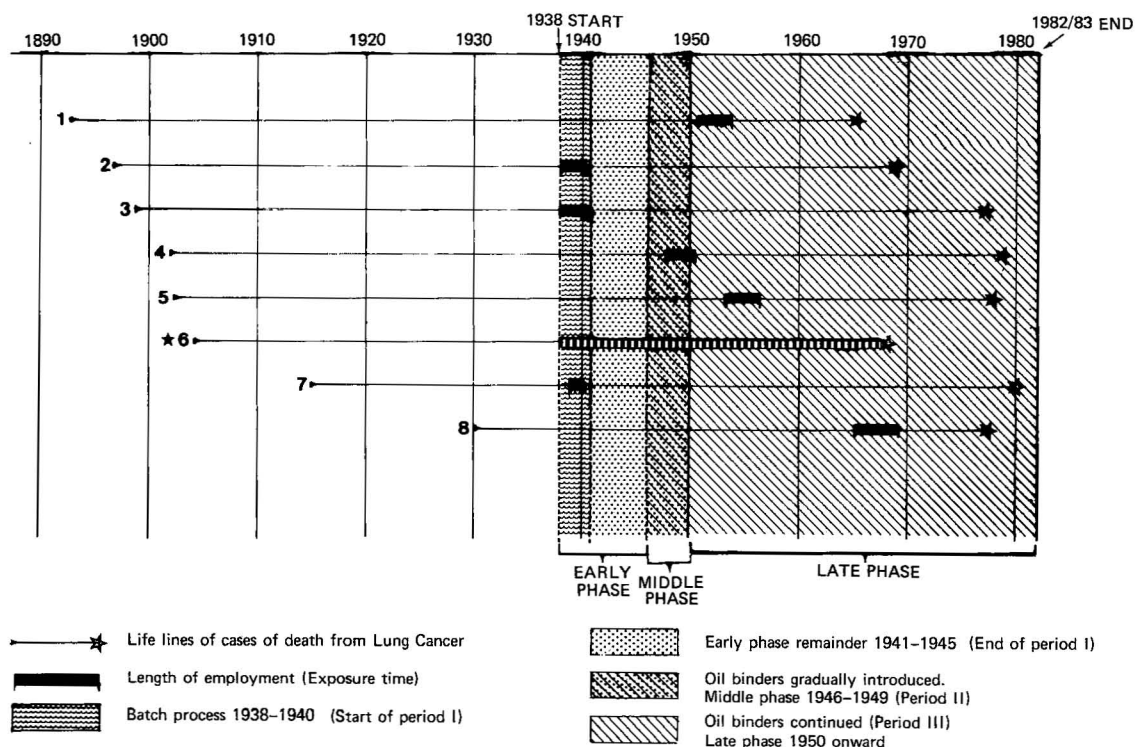


**Figure 1.** Scheme of the lung cancer deaths (case number to the left) among workers in the rock-wool/slag-wool production subcohort in Sweden (Skövde) by time of birth and death, technological phase, and length of exposure. No lung cancer deaths occurred among the Laxå workers. The occupational codes, given in 1979, of the cases were as follows: 29 (transport and other unspecified work) (case 1); 30 (unspecified production work) (case 4); 31 (work in furnace department) (cases 2 and 8); 32 (work on production line) (cases 5 and 7); 33 (manual work) (case 3); and 62 (maintenance, repair work) (case 6). (\* case 6 depicted as a striped bar due to the questionable validity of diagnosis (secondary tumor of lung, primary tumor with site uncertain))

trachea, bronchus, and lung — were distributed according to the technological phase at first exposure. The reader is referred to the main report (3) for an explanation of the concepts used, ie, the early, middle, and late technological phase. Table 6 presents the results for rock wool/slag wool, and table 7 for glass wool.

An excess of lung cancer cases in the subgroup of persons who began their exposure 30 years or earlier before death was observed in the phase designated as "early."

## Comments

A full discussion of the data analyses and their results is found in the joint report (3).

The Swedish section describes the data collection and presents some selected results from the analyses of the Swedish cohort. We wish to mention the high rate of traced persons in the follow-up of the cohort. This result was possible to achieve by means of an exhaustive use of register information available on residents in Sweden — at present as well as in the past — with due regard paid to the fallacies and deficiencies of each source. It is also noteworthy that indispensable assist-

ance was kindly given by colleagues in the neighboring Nordic countries, in the successful follow-up of re-emigrated persons of the cohort.

The reader is reminded that the excess risk of lung cancer in the total European study population is to a great extent localized to the group of  $\geq 30$  years of follow-up after first exposure. This applies both for slag/rock wool and for the glass-wool production subcohorts. A sizable proportion of the lung cancer cases derive from the Swedish cohort. It should also be noted that this excess risk was observed among persons with less than four years of employment. A detailed description of the lung cancer deaths in the Swedish cohort is given in figure 1 (slag/rock wool) and in figure 2 (glass wool).

When considering the short periods of exposure (one to four years) in many of the lung cancer cases with a long time of follow-up, we feel it proper to keep in mind that the association between the risk and the work under study is highly susceptible to confounding factors, both inside and outside the factory. These factors may consist of life-style characteristics of the individuals or of environmental factors related also to other jobs and exposures than those of the MMMF industry. Such factors may have operated either before or after the employment in this industry. We wish

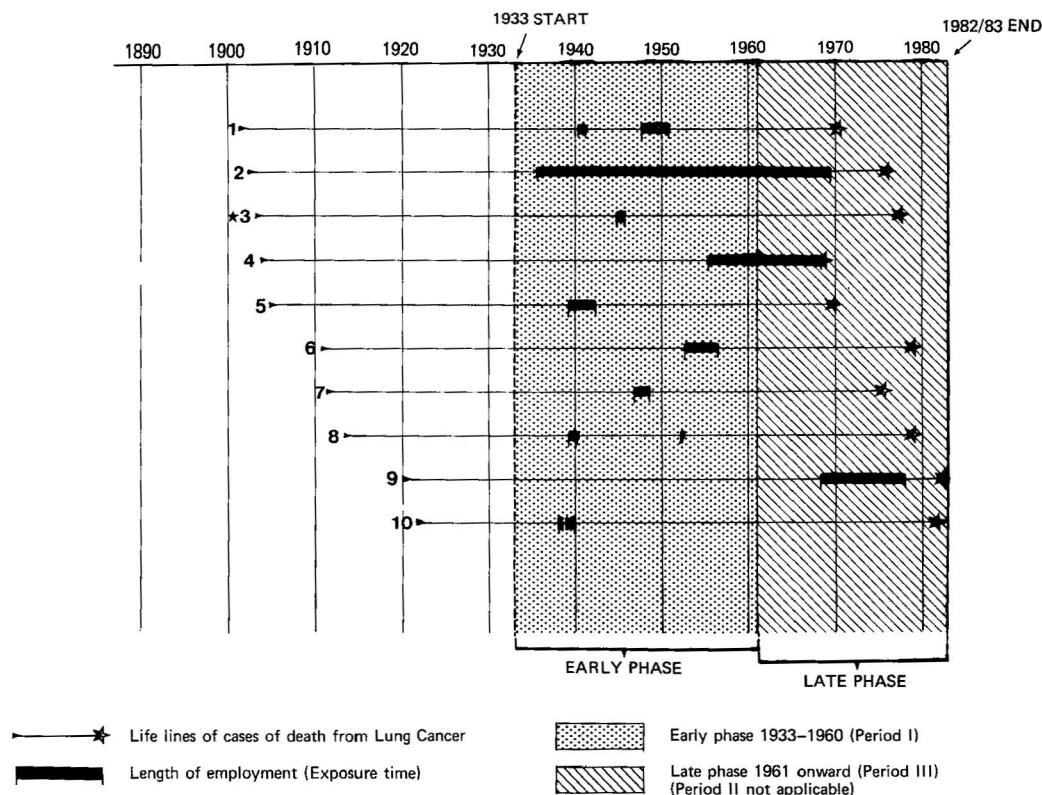


**Figure 2.** Scheme of the lung cancer deaths (case number to the left) among workers in the glass-wool production subcohort in Sweden (Billesholm) by time of birth and death, technological phase, and length of exposure. [★ case 3 is the stomach cancer death referred to in the text under the Discussion in the joint report (3)]

to align ourselves with the prudent judgement made by Peto et al (2), saying that the "short-term workers may suffer consistently higher mortality than long-term workers, as they constitute a self-selected sub-group."

Smoking of cigarettes has been discussed as a confounding factor in the main report (3). We have no objection to this and only wish to emphasize that the dismissal of the smoking factor as a causative agent rests on the assumption that the smoking habits at least 18–20 years before death from lung cancer did not differ significantly between the index group and the population of reference. We have split opinions on this issue. One of us (PW) holds this to be a reasonable assumption, whereas the other (AMB) regards it as questionable.

In the main report observations have been made concerning differences in estimates of lung cancer risk depending on the use of regional data as rates of reference for mortality or incidence. We have chosen not to present analyses of cancer risks according to regional rates for calculation of expected numbers of cases and deaths. The reason is the considerable variation in death rates between the Swedish counties and the significant differences between them with regard to type of industry and degree of urbanization. The county of Skaraborg, dominated by agriculture — and con-

taining the Skövde factory, is known to have the lowest death rate level for lung cancer of the Swedish counties.

It has been demonstrated in the Swedish Cancer-Environment Register of 1961–1973 (1) that, in counties where agriculture occupies a significant portion of the economic activity, lung cancer risks are lower — averaging 45–65 % of the national rate. This observation has also been confirmed by Wiklund (4). It means that in counties where the economic life is dominated by agriculture, the standardized mortality ratio for lung cancer in a study cohort drawn from industry may be unduly inflated, since the expected numbers are significantly below national average levels. Such a situation may well arise in the subcohort derived from the Rockwool factory at Skövde. Conversely, if the region/county contains a large conurbation, the expected numbers for lung cancer will be higher than the national average levels, due to the high rates of lung cancer mortality in such areas, and will lead to underestimations of existing risks. This possibility may well apply to Malmöhus County, containing the Gullfiber glass-wool production plant and also having the city of Malmö within its boundaries. When regional rates are applied for the analysis of cancer risks in Sweden, caution in the interpretation is well advised.

## Conclusions

We have focused in our comments on some aspects of the data analyses and the reliability of our data sources, which, in our view, should be taken into account when the results are interpreted. In reference to the conclusion drawn in the joint report of the European study group, we wish to emphasize that the causal nature of the association between the risk of lung cancer and the work environment has not been proved. The evidence provided by the study is at best suggestive — not conclusive. It is a reasonable hypothesis that the work conditions, including exposure to MMMF during the early production phase have contributed to the risk of lung cancer in the Swedish cohort. This study does not, however, in our opinion, provide sufficient evidence to draw the scientific conclusion that this is the true explanation for the findings.

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