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Cancer incidence among European man-made vitreous fiber production workers

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Objectives This study analyzed cancer incidence among man-made vitreous fiber workers.

Methods A cancer incidence follow-up was conducted among 3685 rock-slag wool (RSW) and 2611 glass wool (GW) production workers employed for ≥ 1 year in Denmark, Finland, Norway, or Sweden, and the standardized incidence ratios (SIR) were calculated on the basis of national incidence rates.

Results Overall cancer incidence was close to expectation. Lung cancer incidence was increased among the RSW [SIR 1.08, 95% confidence interval (95% CI) 0.85—1.36] and GW (SIR 1.28, 95% CI 0.91—1.74) workers. For both subcohorts, a trend was suggested for time since first employment (P-value for linear trend 0.1 and 0.2, respectively). Neither subcohort showed an association with employment during the early technological phase, when fiber exposure was high. The incidence of oral, pharyngeal, and laryngeal cancer was increased among the RSW (SIR 1.46, 95% CI 0.99—2.07) and the GW (SIR 1.41, 95% CI 0.80—2.28) subcohorts. Despite a trend in risk for these neoplasms among the GW workers with time since first employment, the lack of a positive relation with other indirect indicators of fiber exposure points against a causal interpretation. No association between RSW or GW exposure and the risk of other neoplasms was suggested.

Conclusions These lung cancer results are similar to those of a mortality study that included a larger number of factories. For other cancers there was no suggestion of an association with RSW or GW exposure.

Key terms epidemiology, glass wool, man-made vitreous fibers, neoplasms, rock wool, slag wool.

Of the man-made vitreous fibers (MMVF), glass wool (GW) and rock-slag wool (RSW) are extensively used in thermal and acoustical insulation applications, typically in construction and shipbuilding. The results of carcinogenicity studies on animals, mainly based on intracavitary infection and similarities to asbestos (fibrous aspect and inhalability), indicate that man-made vitreous fibers are possible human carcinogens (1). Unlike asbestos, however, they are synthetic and amorphous, with lower biopersistence in lung tissues.

Since 1976, the International Agency for Research on Cancer (IARC) has coordinated a cohort study on mortality and cancer incidence among workers of 13 factories manufacturing man-made vitreous fibers in 7 European countries (2). The results of a mortality follow-up

to 1990—1991 showed an increased risk of lung cancer among both RSW and GW workers. In the latter group, no increase was present when local mortality rates were used. Among RSW workers, the risk of lung cancer was elevated both with national and local reference rates and was present in 5 out of 7 factories. The risk increased, although not significantly so, with time since first employment and duration of employment. Mortality from other causes of death did not suggest any association with employment in the man-made vitreous fiber industry (3, 4).

In the study of carcinogenic hazards, data on cancer incidence are, in general, superior to data on mortality because of the larger number of incident cases when compared with the number of deaths, the possibility of an

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association between exposure and survival rather than cancer induction, and the better quality of cancer registration as compared with death certification. In the IARC study, 9 of the 13 factories, producing either RSW or GW, are located in countries covered by cancer registration. We conducted therefore a cancer incidence analysis, aimed to corroborate the results of the mortality analysis for neoplasms with a poor survival rate and to investigate the incidence of neoplasms with relatively good prognosis.

Subjects and methods

The population under study consisted of production workers employed for more than 1 year in 9 factories in Denmark, Finland, Norway, or Sweden between the year production was started (ranging from 1933 to 1950) and 1977 (table 1). The cancer incidence follow-up could not be performed in the remaining 4 factories from the United Kingdom, Germany, and Italy because of the lack of cancer registration. The workers were identified from personnel records and were followed for cancer incidence from the year production was started until 1994 (Denmark) or 1995 (other 3 countries) through linkage with the files of nationwide cancer registries. The completeness of the cohort was confirmed by the even distribution of age and calendar year of hire among the workers. Our current analysis was based on data from 6296 workers, which provided 161 085 person-years of observation. Among them, there were 3685 RSW workers (92 562 person-years) and 2611 GW workers (68 523 person-years) (table 1). The individual work histories were known until about 1977 (since they have not been updated thereafter).

The follow-up was complete for 94.2% of the cohort, the completeness rate ranging between 89.8% and 98.3% in the different factories. A total of 5.0% of the workers emigrated during the follow-up. The rate of emigration was particularly high in Sweden (7.1%) and Denmark (4.1%).

The workers contributed person-years of observation between the beginning of the 2nd year of employment and the end of follow-up or exit (death, cancer diagnosis, emigration, last contact or last date of employment for subjects lost to follow-up). This period was also used to classify the subjects according to time since first employment, divided into the following 4 categories: 1—10, 10—19, 20—29 and ≥ 30 years. In the analysis by duration of employment, the workers were divided into the following 5 categories: 1—4, 5—9, 10—19, and ≥ 20 years. In the analysis of duration of employment, we applied a 15-year lag time to take into account the lack of employment history after 1977. Altogether 33.8% of the

person-years occurred ≥ 20 years since first employment (32.3% for RSW workers and 35.7% for GW workers).

We divided the period of man-made vitreous fiber production in each factory into an early, intermediate, and late technological phase (5). Airborne levels of man-made vitreous fibers were likely to be highest during the early phase and lowest during the late phase. In the GW factories and in RSW factory 8, we identified only an early and a late phase, and in factory 5 only an intermediate and a late phase were found. We allocated workers to the phase within which their date of first employment occurred. Among the RSW workers, 280 were classified into the early technological phase, 310 into the intermediate phase, and 3095 into the late phase. For the GW workers, these figures were 941, 0, and 1670, respectively.

Reference rates for national cancer incidence were computed at each cancer registry. The cancer incidence diagnoses were coded nationally according to the revision of the International Classification of Diseases (ICD) in effect at the time of the event, and they were converted at IARC to the 7th ICD revision. The reference rates were linearly extrapolated back to the date that man-made vitreous fiber production was started when this date was prior to the availability of the rates.

We derived the number of expected cases by multiplying the accumulated person-years by the national reference rates across gender, age, and calendar-year strata and calculated the standardized incidence ratios (SIR) by dividing the number of observed and expected cases (6). The program "Person Years" (7) was used to estimate the individual contribution to each stratum and to calculate the SIR values and 95% confidence intervals (95% CI) on the assumption of a Poisson distribution of expected cases.

Table 1. Factories and populations included in the study.

| N | Country | Year of start of technological phase | | | Workers (N) | Person-years (N) |
|-----------------------|---------|--------------------------------------|--------------|------|-------------|------------------|
| | | Early | Intermediate | Late | | |
| <i>Rock-slag wool</i> | | | | | | |
| 1 | Denmark | 1937 | 1941 | 1954 | 1358 | 30 948 |
| 3 | Norway | 1950 | 1955 | 1957 | 193 | 5 174 |
| 4 | Norway | 1940 | 1947 | 1956 | 230 | 6 616 |
| 5 | Norway | - | 1948 | 1961 | 384 | 9 703 |
| 8 | Sweden | 1943 | - | 1951 | 373 | 10 496 |
| 9 | Sweden | 1938 | 1946 | 1950 | 1147 | 29 624 |
| Total rock-slag wool | | | | | 3685 | 92 562 |
| <i>Glass wool</i> | | | | | | |
| 2 | Finland | 1941 | - | 1960 | 367 | 9 858 |
| 6 | Norway | 1935 | - | 1961 | 362 | 9 737 |
| 7 | Sweden | 1933 | - | 1961 | 1882 | 48 928 |
| Total glass wool | | | | | 2611 | 68 523 |
| Grand total | | | | | 6296 | 161 085 |

Results

Table 2 reports the detailed results of cancer incidence among the man-made vitreous fiber workers. Overall cancer incidence was close to expectation (792 cases, SIR 0.98, 95% CI 0.91—1.05). No significant increase was noted in the analyses by gender, process, or factory.

The overall SIR for lung cancer was 1.15 (113 cases, 95% CI 0.94—1.38), and it was stronger in the GW subcohort than in the RSW subcohort (table 2).

A nonsignificant increased risk cancer was present for lung in all 3 GW factories and in 2 of the 6 RSW factories ($P < 0.05$ for 1 of them) (table 3). Two of the RSW factories showed a nonsignificant decrease in risk. The analysis by time since first employment suggested a nonsignificant trend for both the RSW workers ($P = 0.1$) and the GW workers ($P = 0.2$) (table 4). No difference in risk was found according to the duration of employment or the technological phase at first employment.

A nonsignificant increase in the incidence of oral, pharyngeal, and laryngeal cancer was found for the RSW (31 cases, SIR 1.46, 95% CI 0.99—2.07) and the GW (16 cases, SIR 1.41, CI 0.80—2.28) workers (table 2). The increase had occurred in all but 3 factories (table 3) although it was statistically significant only for one. The risk of these cancers increased with increasing time since first employment in both the RSW and GW subcohorts (table 5) although the trend was significant only for the latter. In both subcohorts, the workers first employed during the late technological phase experienced a higher

incidence rate than did the other workers. For the RSW workers, an inverse trend was suggested with duration of employment.

A nonsignificant increase in the incidence of pancreatic cancer was found for the RSW workers, and a nonsignificant increase was also present for bladder cancer among the GW workers (table 2). For no other cancer site was there either a significantly increased overall risk (table 2) or a suggestion of a trend according to time since first employment or duration of employment (results not shown in detail). One case of mesothelioma had been registered for a worker employed for 1.5 years in RSW factory 9 (Sweden).

Discussion

The study included over 160 000 person-years of observation among workers with at least 1 year of employment. The results did not provide any clue of an association between employment in the man-made vitreous fiber industry and neoplasms from organs other than lung or the oral cavity, pharynx or larynx.

The results on lung cancer incidence were similar, as expected, to those based on mortality data (3, 4); for the same population, the standardized mortality ratio, based on 76 deaths, was 1.08 (95% CI 0.85—1.36), which was close to the overall SIR of 1.15.

The suggestion of trend for lung cancer risk according to time since first employment among the RSW

Table 2. Cancer incidence among workers with ≥ 1 years of employment by production process, both genders combined. (SIR = standardized incidence ratio, 95% CI = 95% confidence interval)

| Cancer site ^a | Total cohort | | | Rock-slag wool cohort | | | Glass wool cohort | | |
|--|----------------|------|-----------|-----------------------|------|-----------|-------------------|------|-----------|
| | Observed cases | SIR | 95% CI | Observed cases | SIR | 95% CI | Observed cases | SIR | 95% CI |
| All malignant neoplasms (140—205) | 792 | 0.98 | 0.91—1.05 | 468 | 0.97 | 0.88—1.06 | 324 | 0.99 | 0.89—1.11 |
| Oral cavity, pharynx (140—148) | 38 | 1.65 | 1.17—2.26 | 27 | 1.84 | 1.22—2.68 | 11 | 1.31 | 0.65—2.34 |
| Esophagus (150) | 8 | 0.85 | 0.37—1.68 | 6 | 1.03 | 0.38—2.24 | 2 | 0.56 | 0.07—2.02 |
| Stomach (151) | 53 | 1.02 | 0.76—1.33 | 29 | 0.99 | 0.66—1.42 | 24 | 1.05 | 0.67—1.57 |
| Colon, rectum (153—154) | 87 | 0.88 | 0.71—1.09 | 57 | 0.95 | 0.72—1.23 | 30 | 0.78 | 0.53—1.12 |
| Pancreas (157) | 26 | 0.95 | 0.62—1.40 | 17 | 1.06 | 0.62—1.70 | 9 | 0.80 | 0.37—1.52 |
| Larynx (161) | 9 | 0.94 | 0.43—1.79 | 4 | 0.61 | 0.17—1.56 | 5 | 1.68 | 0.55—3.93 |
| Oral cavity, pharynx, larynx (140—148,161) | 47 | 1.44 | 1.06—1.92 | 31 | 1.46 | 0.99—2.07 | 16 | 1.41 | 0.80—2.28 |
| Lung (162.0—162.1) | 113 | 1.15 | 0.94—1.38 | 73 | 1.08 | 0.85—1.36 | 40 | 1.28 | 0.91—1.74 |
| Breast (170) | 33 | 0.91 | 0.62—1.27 | 4 | 0.42 | 0.11—1.08 | 29 | 1.08 | 0.72—1.55 |
| Cervix uteri (171) | 7 | 0.92 | 0.37—1.91 | 3 | 1.52 | 0.31—4.45 | 4 | 0.71 | 0.19—1.83 |
| Other female genital organs (172—174,176) | 13 | 1.23 | 0.65—2.10 | 5 | 1.93 | 0.63—4.51 | 8 | 1.00 | 0.43—1.97 |
| Prostate (177) | 97 | 0.89 | 0.72—1.09 | 62 | 0.92 | 0.71—1.18 | 35 | 0.84 | 0.59—1.17 |
| Kidney (180) | 15 | 0.50 | 0.28—0.83 | 9 | 0.50 | 0.23—0.95 | 6 | 0.50 | 0.18—1.09 |
| Bladder (181) | 55 | 1.06 | 0.80—1.38 | 32 | 0.91 | 0.62—1.29 | 23 | 1.39 | 0.88—2.08 |
| Skin melanoma (190) | 20 | 0.92 | 0.56—1.41 | 10 | 0.77 | 0.37—1.41 | 10 | 1.13 | 0.54—2.08 |
| Leukemia (204) | 16 | 0.92 | 0.53—1.50 | 8 | 0.73 | 0.32—1.44 | 8 | 1.25 | 0.54—2.46 |
| Lymphoma, myeloma (200—203) | 37 | 0.98 | 0.69—1.35 | 23 | 1.02 | 0.65—1.53 | 14 | 0.92 | 0.50—1.54 |
| Other malignant neoplasms | 161 | 0.98 | 0.83—1.14 | 96 | 0.95 | 0.77—1.16 | 65 | 1.01 | 0.78—1.29 |

^a Code of the International Classification of Diseases in parentheses.

Table 3. Incidence of cancers of the lung and of the oral cavity, pharynx and larynx by factory. (SIR = standardized incidence ratio, 95% CI = 95% confidence interval)

| Factory number & country | Oral cavity, pharynx, larynx | | | Lung cancer | | |
|--------------------------|------------------------------|------|-----------|----------------|------|-----------|
| | Observed cases | SIR | 95% CI | Observed cases | SIR | 95% CI |
| <i>Rock-slag wool</i> | | | | | | |
| 1 Denmark | 15 | 1.70 | 0.95—2.80 | 35 | 1.00 | 0.70—1.39 |
| 3 Norway | 2 | 1.80 | 0.37—5.28 | 2 | 0.62 | 0.07—2.23 |
| 4 Norway | 2 | 1.39 | 0.17—5.02 | 10 | 2.41 | 1.15—4.43 |
| 5 Norway | 7 | 2.72 | 1.09—5.61 | 11 | 1.54 | 0.77—2.76 |
| 8 Sweden | 2 | 1.01 | 0.12—3.63 | 2 | 0.40 | 0.05—1.46 |
| 9 Sweden | 3 | 0.57 | 0.12—1.66 | 13 | 1.01 | 0.54—1.73 |
| <i>Glass wool</i> | | | | | | |
| 2 Finland | 3 | 1.81 | 0.37—5.28 | 8 | 1.18 | 0.51—2.33 |
| 6 Norway | 5 | 2.10 | 0.77—5.56 | 8 | 1.32 | 0.57—2.60 |
| 7 Sweden | 8 | 1.05 | 0.45—2.08 | 24 | 1.30 | 0.83—1.94 |

Table 4. Risk of lung cancer among man-made vitreous fiber workers by time since first employment, duration of employment and technological phase at first employment. (O = observed number of cases, RR = relative risk, 95% CI = 95% confidence interval, ref = reference category, NA = not applicable)

| | Rock-slag wool | | | Glass wool | | |
|--|----------------|-----|----------|------------|-----|----------|
| | O | RR | 95% CI | O | RR | 95% CI |
| Years since first employment ^a | | | | | | |
| 1—9 | 7 | 1.0 | ref | 10 | 1.0 | ref |
| 10—19 | 21 | 1.8 | 0.7—4.7 | 15 | 1.9 | 0.8—4.8 |
| 20—29 | 25 | 2.4 | 0.9—6.8 | 15 | 2.3 | 0.6—9.2 |
| ≥30 | 20 | 3.0 | 0.8—10.5 | 15 | 2.3 | 0.6—9.2 |
| Test for linear trend, P-value | 0.1 | | | 0.2 | | |
| Years of employment (15-year lag) ^b | | | | | | |
| 1—4 | 33 | 1.0 | ref | 23 | 1.0 | ref |
| 5—9 | 11 | 1.0 | 0.5—2.1 | 8 | 0.8 | 0.3—2.0 |
| 10—19 | 10 | 1.2 | 0.5—2.6 | 4 | 0.8 | 0.3—2.4 |
| ≥20 | 5 | 2.0 | 0.7—6.2 | 1 | 0.7 | 0.08—5.3 |
| Test for linear trend, P-value | 0.4 | | | 0.5 | | |
| Technological phase at first employment ^c | | | | | | |
| Late | 50 | 1.0 | ref | 20 | 1.0 | ref |
| Intermediate | 14 | 0.8 | 0.4—1.7 | NA | NA | NA |
| Early | 9 | 0.8 | 0.3—2.0 | 20 | 0.6 | 0.2—1.9 |
| Test for linear trend, P-value | 0.5 | | | | | |

^a The relative risk has been adjusted for gender, age, country, and technological phase.

^b The relative risk has been adjusted for gender, age, country, time since first employment, and technological phase.

^c The relative risk has been adjusted for gender, age, country, and time since first employment.

workers of this analysis confirmed the findings of the earlier mortality analysis (3, 4). The suggestion of an increased risk according to time since first employment among the GW workers represents an original finding of the present analysis that, however, was not confirmed by the mortality analysis based on the larger population of GW workers, including also factories from the United Kingdom and Italy. After control for time since first em-

Table 5. Risk of cancer of the oral cavity, pharynx, and larynx among man-made vitreous fiber workers by time since first employment, duration of employment, and technological phase at first employment. (O = observed number of cases, RR = relative risk, 95% CI = 95% confidence interval, ref = reference category, NA = not applicable)

| | Rock-slag wool | | | Glass wool | | |
|--|----------------|-----|----------|------------|------|----------|
| | O | RR | 95% CI | O | RR | 95% CI |
| Years since first employment ^a | | | | | | |
| 1—9 | 5 | 1.0 | ref | 2 | 1.0 | ref |
| 10—19 | 12 | 2.0 | 0.6—6.5 | 7 | 9.1 | 1.6—52.7 |
| 20—29 | 9 | 2.1 | 0.5—8.7 | 7 | 12.2 | 1.1—132 |
| ≥30 | 5 | 3.1 | 0.5—20.0 | 7 | 12.2 | 1.1—132 |
| Test for linear trend, P-value | 0.3 | | | 0.03 | | |
| Years of employment (15-year lag) ^b | | | | | | |
| 1—4 | 14 | 1.0 | ref | 7 | 1.0 | ref |
| 5—9 | 3 | 0.5 | 0.1—1.7 | 6 | 1.4 | 0.5—4.5 |
| 10—19 | 1 | 0.2 | 0.03—1.8 | - | - | - |
| ≥20 | - | - | - | 1 | 1.1 | 0.1—10.5 |
| Test for linear trend, P-value | 0.07 | | | 0.6 | | |
| Technological phase at first employment ^c | | | | | | |
| Late | 25 | 1.0 | ref | 6 | 1.0 | ref |
| Intermediate | 5 | 0.4 | 0.2—1.5 | NA | NA | NA |
| Early | 1 | 0.1 | 0.01—1.2 | 10 | 0.6 | 0.1—3.4 |
| Test for linear trend, P-value | 0.04 | | | | | |

^a The relative risk has been adjusted for gender, age, country, and technological phase.

^b The relative risk has been adjusted for gender, age, country, time since first employment and technological phase.

^c The relative risk has been adjusted for gender, age, country, and time since first employment.

ployment, there was no excess risk for the workers of either subcohort first employed in the early technological phase, when estimated fiber exposure was at its height.

An increase in the incidence of oral and pharyngeal cancer was found for the RSW workers. Similar results were obtained in the earlier mortality analysis (8 deaths, standardized mortality ratio 2.23, 95% CI 0.96—4.39). However, the lack of a clear relationship with time since first employment, the lack of a similar increase in other cohorts of RSW workers (8), and the fact that 14 out of the 27 cases reported in table 2 were cases of cancer of the lip (ICD-9 140) point against the hypothesis of a causal association with exposure to RSW fibers. When we combined cancers of the oral cavity, the pharynx, and the larynx (tables 2, 3, 5), the increase in risk was similar for the RSW and GW subcohorts. There was a trend with time since first employment for both (and significant for the GW subcohort) and a lower risk for workers first employed in the early technological phase. The findings in the GW subcohort were mainly due to laryngeal cancer, and they paralleled the results of a previous study (9).

In conclusion, the increase in lung cancer mortality among RSW workers was also detected in this incidence

analysis, which, in addition, provided evidence for an absence of a detectable risk of neoplasms, such as prostate and breast cancers, that cannot be fully assessed in a mortality analysis because of the relatively good survival rate. As in the mortality analysis, the increased risk of lung cancer among RSW workers cannot be attributed to fiber exposure, although this association remains a plausible, but unproved, hypothesis (4). We have so far not been able to disentangle the contributions to the increase in lung cancer risk of extraoccupational factors, such as tobacco smoking, and occupational factors, including RSW, other agents occurring in the RSW industry and agents occurring outside the RSW industry (10). A case-referent study of the RSW cohort is in progress to elucidate these questions.

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