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Cancer incidence, mortality and exposure-response among Swedish man-made vitreous fiber production workers

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Objective The objective of this study was to provide an extended follow-up of workers in three Swedish plants producing man-made vitreous fibers (MMVF).

Method Mortality and cancer incidence was investigated among 3539 male and female workers, employed for at least one year before 1978. Mortality was followed from 1952 to 1990 and cancer incidence from 1958 to 1989. National and regional mortality and cancer incidence rates were used to calculate the expected numbers.

Results Twenty-seven lung cancer deaths were observed compared with 23 expected (standardized mortality ratio 117, 95% confidence interval 81—176), based on regional mortality. With a latency time of 30 years, the lung cancer risk was significantly elevated, but no trend was found for the standardized mortality ratio with increasing duration of exposure to MMVF. The lung cancer and stomach cancer mortality was higher in the rock wool industry than in the fiber glass industry. Fiber exposure from 1938 to 1990 was estimated in the two rock wool plants by applying a model for historical fiber exposure estimation, specific for different job titles in the rock wool production industry. No relationship was found between individually cumulated rock wool fiber exposure and lung cancer or stomach cancer risk.

Conclusions The numbers of lung cancers and stomach cancer cases were low and did not therefore allow more general conclusions regarding the cancer hazard for exposed workers. A large European study in progress will probably allow more precise conclusions.

Key terms exposure assessment, glass wool, man-made mineral fibers, rock wool, slag wool.

Exposure to man-made mineral fibers (MMVF) has induced pleural and peritoneal cancers in experimental animals (1). To investigate mortality and cancer incidence for people exposed to MMVF, two large epidemiologic studies were started in the middle of the 1970s, one in Europe (2, 3) and one in the United States (4). The European study comprised 21 967 men and women at 13 plants in seven countries and was coordinated by the International Agency for Research on Cancer in Lyon. Three of the plants are located in Sweden, one fiber glass plant and two rock wool plants. In the European cohort an increased lung cancer risk was suggested for workers employed for a short time and exposed before 1945, the so-called "early production phase." Similar results were found in the American study. Both studies are now being updated.

The three Swedish MMVF production plants were followed until 1983 in a separate study (5). An excess of lung cancer cases was found among subjects with short employment time and after 30 years since first exposure. The study has now been extended with seven additional years of follow-up for cancer incidence and 7.5 years for mortality experience (1983-July 1990).

A model was developed to estimate historical MMVF exposure at the job title level in the Swedish rock wool production industry. The development of the model has been described in another report (6). The model was used to study the exposure-response relationship for cumulative MMVF exposure and lung cancer risk in the rock wool industry.

The objective of this study was to determine whether an exposure-response relationship could be demonstrated

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with the improved model for exposure estimation and to examine the implications of the use of national and regional reference rates in calculating expected numbers, in addition to extending the follow-up.

Subjects and methods

Study population

Three MMVF production plants in Sweden were included in the cohort, one large fiber glass, one large rock wool, and one small rock wool production plant. Personal identification data for the cohort had been stored in a data base during the previous phase of the study. This information was updated by data gathered during visits to the plants, and the subjects were re-identified in the company records. These records hold information on name, personal identification number, employment time, and job type. The information in the data base was completed concerning employment (job title and changes in job titles) between 1 January 1983 and 1 January 1990 from the company records. In that process, additional exposure information was obtained in interviews of management, older employees, trade union representatives, retired workers, and the staff at the departments at each company.

All male and female production workers employed for at least one year in MMVF-exposed work between the time mineral wool production started and 1977 were included in the cohort when it was created in 1977. In the verification procedure 61 subjects were excluded from the original cohort of 3600 subjects for several reasons, such as less than one year of exposure (N = 35), deceased before 1952 (N = 9), or missing in the factory records (N = 10). The reason for excluding persons who died before 1952 was that the follow-up period began that year since no reliable data on causes of deaths were available for earlier years.

Of the remaining 3539 subjects, 245 had emigrated and 41 were lost to follow-up. Twenty percent of the cohort were women, mainly employed in the fiber glass plant and the smaller rock wool plant. There were 1970 subjects from the glass wool plant, 1187 from the large plant, and 382 from the small rock wool plant. The cohort comprised 74 043 person-years of observation.

Follow-up and data analysis

The life outcome of the cohort members was traced in a computerized register of the Swedish population via the clerical parish offices and via the taxation authorities. The mortality analysis was based on data from 3253 subjects, and there were 739 deaths in the cohort. Mortality was studied from 1 January 1952 to 30 June 1990. Underlying causes of death were obtained from the death certificates. Copies of the death certificates were obtained from Statistics Sweden (7), and in a few cases the underlying cause of death was obtained from the clerical parishes.

The diagnoses on the death certificates were checked against the code of the International Classification of Diseases (ICD), for the underlying cause of death, registered at Statistics Sweden. In one case, the coding was found to be erroneous. The death certificate stated the cause of death as stomach cancer, although the ICD (eighth revision) code was 162.1, which is the code for primary lung cancer. The diagnosis in the Swedish cancer register was stomach cancer. In the analyses, this case was retained as stomach cancer.

Information on cancer incidence was obtained from the Swedish Cancer Register for the period 1 January 1958 to 31 December 1989. The group for the cancer incidence study comprised 3224 subjects.

The comparison of cancer deaths and cancer registrations revealed a discrepancy for another cohort member in addition to the aforementioned stomach cancer case. The cause of death for this person was "lung cancer, not verified as primary," correctly coded as 163 according to to ICD (seventh revision) code in the cause of death register. The cancer register code for the same person was 199.9 (cancer at unknown site). The discrepancy was caused by the different criteria and different data source used for the registers of deaths and cancer. The codes were correctly applied according to the criteria used. Through additional diagnostic efforts it had been found that the tumor was probably a secondary lung cancer; see reference 5. However, the coding of this case was not corrected since such a procedure would have generated a bias in the standardized mortality ratios. No similar accuracy check was possible for the reference rates on which the expected numbers were based, and corrections carried out only among the exposed would have systematically reduced the observed cases at certain diagnoses without a corresponding reduction of the expected numbers. In the calculations for cancer incidence code 199.9 was used.

The expected numbers of deaths and cancers were calculated according to the person-year method (8), accounting for differences due to age, calendar year, gender, and geographic region (county). The three plants were located in three different counties. All of the results have been presented with regional reference rates. However, in table 2 in the results section, national reference rates were added for comparison.

The standardized mortality ratios (SMR) and standardized incidence ratios (SIR) were calculated with the OCMAP-PC computer program (9).

There were no lung cancer cases among the women in the cohort. Thus it was not possible to estimate the lung cancer risk for women. Since fiber exposure was approximately similar for both genders, the results were presented for the men and women combined, but separate analyses were also done.

Exposure-response analysis

The fiber exposure was assessed for 1487 subjects in the rock wool industry (6). Cumulative fiber exposure was estimated as the integral of exposure intensity over calendar time (ie, the employment time in exposed zones was multiplied by the estimated mean fiber exposure, integrated over all of the exposure periods). The cumulative exposure for each subject was classified as low, intermediate, or high. The cutoff points between the classes were 1.0 $f \cdot ml^{-1} \cdot$ year and 2.0 $f \cdot ml^{-1} \cdot$ year so that the distribution of lung cancer cases would be even over the exposure strata.

The exposure-response analysis used the SMR for lung cancer mortality as the outcome variable. Its analysis was based on 13 cancer cases. The SMR analyses were performed using a model describing plant-specific exposure and another model describing exposure specific for job title.

The exposure-response analysis used the SIR for stomach cancer incidence as the outcome variable for the 13 stomach cases in the rock wool industry. Cumulative fiber exposure was determined from the job-specific fiber exposure, and the cutoff points were the same as for lung cancer.

The relative risk incidence rate ratio (RR) for lung cancer among the men was also calculated by a Poisson regression, in which the lowest exposure group was used as a reference. The same cutoff points were used as in the SMR analysis.

Different lagging times (ie, risk estimations that disregard the last 5 or 20 years of exposure) were used to investigate the possible influence of late and early exposures on the risk (10).

Results

Mortality

The total mortality in the cohort was close to the expected. Twenty-seven lung cancer cases were found versus 23 expected [SMR 117, 95% confidence interval (95% CI) 81—176]. An increased risk for deaths from external causes was observed, while the number of kidney cancer deaths was lower than expected (table 1).

At the large rock wool plant an increased lung cancer risk was observed (SMR 240, 95% CI 124—419). At the same factory there was a significantly increased risk of deaths from external causes (SMR 154, 95% CI 105—219) (table 2). No significantly increased risk for mortality from other diseases was observed at any of the factories (tables 1 and 2).

Lung cancer mortality, analyzed from length of employment, is presented in table 3. There was no trend towards an increasing lung cancer risk with increasing exposure duration. For all periods together, the observed risk was larger for rock wool workers than for fiber glass workers.

Mortality after 20 years since first exposure and 30 years since first exposure is presented in tables 4 and 5. The number of observed cases of lung cancer was higher than expected at the glass wool factory and at the larger rock wool plant. At the large rock wool plant eight cases were observed (SMR 260 95% CI 112—512) with 20 years of latency time and six cases with 30 years of latency time (SMR 375, 95% CI 138—826). Although no cases were found at the smaller rock wool plant, there was a significantly increased risk for lung cancer incidence in the three plants taken together with a latency time of 30 years (SMR 171, 95% CI 102—302).

Table 1. Mortality based on regional mortality. (O = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Cause of death[a]	O	E	SMR	95% CI
Total (1—999)	738	720.3	102	95—110
All malignant tumors (140—209)	168	170.0	99	84—115
Esophageal cancer (150)	3	3.0	97	20—283
Stomach cancer (151)	19	17.7	107	60—161
Bowel cancer (152—153)	16	23.4	69	39—111
Liver cancer (155)	2	3.0	63	9—226
Pancreatic cancer (157)	10	10.9	91	44—168
Lung cancer (162)	27	23.0	117	81—176
Prostatic cancer (185)	21	17.6	120	74—183
Bladder cancer (188)	6	4.8	127	48—277
Kidney cancer (189)	1	7.1	14	1—79
Brain tumor (191)	5	5.0	100	33—233
Malignant lymphomas (200—202)	7	6.4	110	44—226
Myeloma (203)	6	3.3	181	66—393
Leukemia (204—207)	6	6.8	89	33—193
Circulatory diseases (390—458)	371	366.5	101	91—112
Ischemic heart diseases (410—414)	228	240.9	95	83—108
Cerebrovascular diseases (430—438)	60	62.4	96	73—124
Respiratory diseases (460—519)	44	41.1	107	78—144
Asthma, bronchitis, emphysema (490—493)	17	13.1	129	75—207
Digestive diseases (520—577)	25	25.4	98	64—145
Liver cirrhosis (571)	6	7.0	82	30—179
Genitourinary diseases (580—629)	8	12.7	63	27—124
Nephritis, nephrosis (580—584)	2	3.6	55	7—200
Death from external causes (E800—999)	82	61.9	132	105—164
Suicide (E950—E959)	29	24.7	117	79—169

[a] Codes of the International Classification of Diseases (eighth revision) in parentheses.

Table 2. Mortality for the men and women combined in 1952—1990, presented by factory. (0 = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Cause of death[a]	0	Regional reference rates			National reference rates		
		E	SMR	95% CI	E	SMR	95% CI
All cancers							
Glass wool plant	102	101.6	100	82—122	100.3	102	83—123
Rock wool, small plant	20	24.3	82	50—127	25.0	77	47—119
Rock wool, large plant	46	44.4	104	76—138	50.5	91	67—122
Lung cancer							
Glass wool plant	14	14.5	97	57—169	13.5	104	62—183
Rock wool, small plant	1	3.3	30	1—167	3.8	26	7—147
Rock wool, large plant	12	5.0	240	124—419	8.9	135	70—236
External causes							
Glass wool plant	40	33.4	120	86—163	34.0	117	84—160
Rock wool, small plant	11	8.4	131	65—234	8.6	128	64—229
Rock wool, large plant	31	20.1	154	105—219	24.3	128	87—181

[a] Codes of the International Classification of Diseases (eighth revision) in parentheses.

Table 3. Mortality from lung cancer by length of employment and with the use of regional reference rates. (0 = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Length of employment (years)	Rock wool				Glass wool			
	0	E	SMR	95% CI	0	E	SMR	95% CI
1—<2	1	1.5	67	2—371	5	3.4	147	48—344
2—9	7	3.5	199	80—410	7	7.6	92	37—190
10—19	3	2.0	148	31—432	1	2.5	39	1—219
≥ 20	2	1.4	143	2—516	1	1.1	94	2—521
Total	13	8.4	155	82—265	14	14.6	96	58—169

Table 4. Mortality from lung cancer in 1952—1990 by length of employment and with the use of 20 years of latency time and regional reference rates. (0 = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Length of employment (years)	Rock wool				Glass wool			
	0	E	SMR	95% CI	0	E	SMR	95% CI
1—< 2	1	0.9	110	28—612	5	2.2	224	73—523
2—9	5	1.9	269	87—627	5	4.4	114	37—266
10—19	1	1.1	87	2—489	—	1.4	0	.
≥ 20	2	1.4	143	17—516	1	1.1	94	2—521
Total	9	5.3	170	78—322	11	9.1	121	68—230

Table 5. Mortality from lung cancer in 1952—1990, calculated with 30 years of latency. (0 = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95% CI = 95% confidence interval)

Factory	0	E	SMR	95% CI
Glass wool plant	8	5.6	143	74—305
Rock wool, small plant	—	0.9	0	.
Rock wool, large plant	6	1.6	375	138—826
Total	14	8.2	171	102—302

No lung cancer cases were found among the women. When the women were excluded from the analysis, the lung cancer SMR increased from 117 to 130.

Cancer incidence

Table 6 presents the total cancer incidence, stomach cancer incidence, and lung cancer incidence during 1958—1989. The rock wool plants showed a slightly increased lung cancer incidence (SIR 165, 95% CI 88—283), while the lung cancer rate in the fiber glass factory was close to the expected (SIR 93). For both fiber types together an SIR 115 of was obtained.

The total number of cancer cases at one of the rock wool plants showed a significantly increased risk with an SIR of 124 (95% CI 100—152) due to an increased risk for stomach cancer (SIR 196, 95% CI 98—351) and lung cancer (SIR 251, 95% CI 129—438).

The distribution of incident lung cancer cases over the employment time categories was similar to the mortality distribution (ie, the cases were found in the 2- to 9-year employment time group) (table 7). Most of the lung cancer cases were observed in the subgroup with two to four years of employment (7 observed versus 2.0 expected, not shown in the table).

Exposure

Thirteen lung cancer cases were observed in the two rock wool plants. The mean cumulative fiber exposure among the lung cancer cases was estimated to be 1.34 f · ml^{-1} · year, which is somewhat lower than the calculated mean cumulative fiber exposure for the other 1474 subjects, whose corresponding mean was 1.44 f · ml^{-1} · year.

A subcohort of furnace workers was created to study the effect of combustion gas exposure, which has been suggested as a confounding exposure due to its content of polycyclic aromatic hydrocarbons (PAH). The subjects classified as furnace workers, or oven workers when cupola furnaces were used and heated with fossil fuel, were included in the subcohort. Work during other times and all other job titles were classified as not exposed to combustion gases. The subcohort also included furnace workers employed in the fiber glass industry when fossil fuels were used for melting glass. MMVF exposure also occurred in the same areas. The SMR for the subgroup exposed to combustion gases was 131 (95% CI 62—410), with four observed lung cancer cases (furnace operators).

In the same way the effect of curing oven fume exposure was analyzed for all the subjects who had ever worked as a line worker for more than one year since the curing ovens were installed. Line workers had the only job for which curing fume exposure was over the background level. MMVF occurred also in these areas. Curing oven gases contain mainly pyrolyzed phenols and formaldehyde. The SMR calculated with 20 years of latency for the subgroup exposed to curing gas fumes was 168 (95% CI 40—325), based on three observed cases.

Table 6. Cancer incidence in 1958—1989. Expected numbers based on regional reference rates for the men and women combined. (O = observed number of deaths, E = expected number of deaths, SIR = standardized incidence ratio, 95% CI = 95% confidence interval)

Type of cancer[a]	O	E	SIR	95% CI
Total cancer				
Glass wool plant	154	197.7	78	66—91
Rock wool, small plant	40	39.3	102	73—139
Rock wool, large plant	91	74.9	124	100—152
Stomach cancer				
Glass wool plant	10	11.1	91	43—166
Rock wool, small plant	2	2.0	103	12—370
Rock wool, large plant	11	5.6	196	98—351
Rock wool, small and large plants	13	7.6	171	91—293
All plants	23	18.7	123	78—185
Lung cancer				
Glass wool plant	17	18.3	93	54—148
Rock wool, small plant	1	3.0	33	1—184
Rock wool, large plant	12	4.7	251	129—438
Rock wool, small and large plants	13	7.8	165	88—283
All plants	30	26.1	115	77—164

[a] Coded according to the International Classification of Diseases (seventh revision).

Exposure-response analysis (rock wool)

Lung cancer

SMR analysis. The observed trend was not consistent with a monotonic (linear) exposure-response relation between lung cancer mortality and cumulative fiber exposure in the plant-specific exposure assessment model (table 8). Neither was there any consistent exposure-response trend when the exposure assessment was based on job title. The highest lung cancer mortality rate was found for the medium-exposed workers, but the numbers of deaths were very low, and the confidence intervals for the SMR in each exposure group were wide, all including SMR = 100.

Poisson regression analysis. The observed trend was not consistent with a monotonic (linear) dose-response relation between cumulative fiber exposure and lung cancer risk among the rock wool workers. Exposure-response analysis by the job-specific exposure model gave the highest relative risk (RR) for the intermediate exposure

Table 7. Lung cancer incidence by length of employment in 1958—1990 (regional rates). (O = observed number of cases, E = expected number of cases, SIR = standardized incidence ratio, 95% CI = 95% confidence interval)

Duration of employment (years)	Rock wool				Glass wool			
	O	E	SIR	95% CI	O	E	SIR	95% CI
1—< 2	1	1.5	69	2—384	3	41	72	15—212
2—9	7	3.3	212	85—437	11	9.6	115	57—205
10—19	3	1.8	163	34—476	1	3.2	31	1—174
≥ 20	2	1.2	161	20—583	2	1.4	145	18—524
Total	13	7.7	165	88—283	17	18.3	93	54—148

Table 8. Exposure-response relationships from two different models used to estimate cumulative exposure to man-made vitreous fibers (MMVF) in two Swedish rock wool plants. (N = number of lung cancer cases, SMR = standardized mortality ratio calculated from regional reference rates, 95% CI = 95% confidence interval)

	Exposure class								
	Low (< 1.0 f · ml⁻¹ · year)			Medium (1.0—2.00 f · ml⁻¹ · year)			High (> 2.0 f · ml⁻¹ · year)		
	N	SMR	95% CI	N	SMR	95% CI	N	SMR	95% CI
Model I (plant specific)	7	201	81—413	4	245	67—621	2	62	8—224
Model II (job group specific)	6	164	66—357	4	256	70—657	3	95	20—278

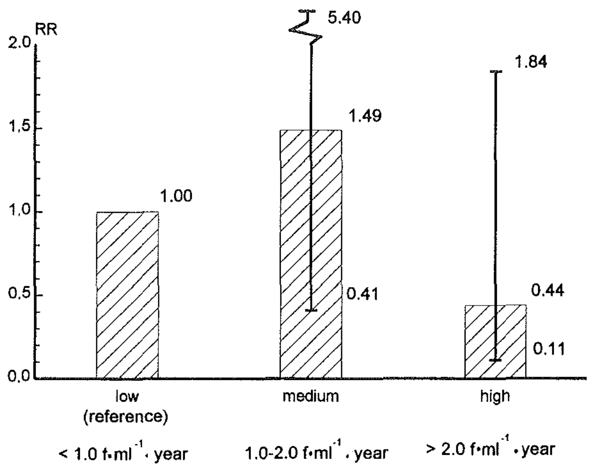

Figure 1. Exposure response analysis (Poisson regression) of 13 lung cancer cases at two Swedish rock wool plants. The relative risk (RR) for lung cancer incidence is shown as a function of cumulative exposure to man-made vitreous fibers in fiber-years per milliliter (f · ml⁻¹ · year). Error bars indicate the 95% confidence interval. (low: N = 6 observed cases, medium: N = 4, and high: N = 3)

group (N = 4, RR 1.49, 95% CI 0.41— 5.40). The highest exposure group (N = 3) showed the lowest risk (RR 0.44, 95% CI 0.11—1.84) (figure 1). The same pattern was found both with 5 years and 20 years of lagging, calculated by omitting the last 5 years or 20 years of exposure, respectively. The plant-specific model showed the same pattern. Again, the numbers were low, giving wide confidence intervals.

Stomach cancer

SIR analysis. The observed trend was not consistent with a monotonic (linear) dose-response relation between stomach cancer and cumulative fiber exposure in the job-specific exposure assessment model. The lowest exposed group (N = 7) had an SIR of 217, the group with intermediate exposure (N = 3) had an SIR of 210, and for the highest exposed group (N = 3) the SIR was 92.

Late phase subcohort

A subcohort was created including those who were employed and exposed to rock wool after only 1948 (large plant) and 1953 (small plant) to examine the effects of possible misclassification due to large fluctuations in exposure during the early production period. At about 1950 technical changes, especially the use of binders and oil in production, reduced the exposure to lower levels, close to those observed today. This analysis was based on eight observed cases, and the total subgroup had an SMR of 159 (95% CI 82—372). The group was classified as merely low and high with the cutoff point at the mean value for the group, 0.84 f · ml⁻¹ · year. The group with low exposure had an SMR of 140, and that with high exposure had an SMR of 183.

Discussion

The lung cancer mortality among the mineral wool production workers was somewhat higher than expected, 27 observed versus 23 expected cases. No trend was obvious when the lung cancer mortality rate was related to duration of exposure, but the lung cancer mortality in the rock wool plants was higher among those employed two to nine years than among those employed long- or short-term.

The lung cancer mortality excess was slightly higher in the rock wool production industry than in the fiber glass industry. The risk excess was also larger when regional reference rates were used rather than national reference rates. The lung cancer incidence showed a similar pattern. A small excess of stomach cancer was also observed. No correlations between cumulative exposure to rock wool fibers and lung cancer or stomach cancer were apparent.

Regional versus national rates

In the European collaboration study the lung cancer risk was higher when national reference rates were used (SMR 125) than with regional rates (SMR 112), and the same findings were observed in the American study (4). Our study showed a reversed pattern.

The lung cancer incidence varies considerably in different counties of Sweden (11). The large rock wool plant is located in the county with the lowest lung cancer incidence (25 cases per 100 000 men), while the fiber glass plant is located in the county with the highest local rate (66 cases per 100 000 men). The average for the entire country is 44 cases per 100 000 men (age-adjusted), and thus the application of national or regional reference rates gives divergent results, as illustrated in table 2. The rock wool and glass wool industries together had an SMR of 117 when based on regional reference rates and an SMR of 103 when based on national reference rates. This finding is consistent with earlier findings (SMR 107) from this cohort (5). Regional reference rates are probably more valid than national rates for calculating expected numbers because they are more representative for the regional conditions affecting mortality and cancer incidence (eg, diet, tobacco and alcohol consumption habits, and environmental factors).

Stomach cancer

In the present study the overall SMR was 107 for stomach cancer, and the SIR for workers in the rock wool plant was 171 (13 observed and 7.6 expected), with a statistically significant increased risk for the men (SIR 186, 95% CI 100—318). A negative exposure-response relationship was observed. In the large European cohort there was a nonsignificant excess of stomach cancer (SIR 115) (2). The cohort in the United States (4) had an SMR of 101 for digestive organs and the peritoneum. Two other publications reported excesses for the digestive system among workers exposed to rock wool (12, 13), but there was no specific reference to the stomach. No excess mortality from stomach cancer was found among wooden house workers exposed to MMVF (14).

Confounding factors

Other substances which are known or suspected cancerogenic agents have been present in MMVF production plants. Some subjects have had high exposures to PAH in the furnace section when fossil fuels were used for heating the ovens. High exposures to PAH may increase the risk for lung cancer (15), but the subgroup of furnace workers did not show any strong excess risk (four observed versus three expected).

Formaldehyde exposure is also of concern for certain job titles, along with pyrolyzed phenols. Formaldehyde is not a strong lung carcinogen (16), and the information on lung effects from phenol compounds is sparse. A subgroup of workers exposed to combustion gases from curing ovens showed an SMR of 168 (3 observed cases versus 1.8 expected).

Possible reasons for the lack of an exposure-response relationship

This study was designed to determine whether the lung cancer excess found in several previous studies among workers employed in early production phases could be due to high peak exposures occurring during earlier time periods and therefore have high cumulative doses in spite of only a few years of work. However, no exposure-response trend was found when lung cancer mortality and incidence were correlated with the estimated cumulative rock wool fiber dose, and there may not be any exposure-response relationship at these low fiber exposure levels. However, there are also other potential explanations.

It may not be possible to demonstrate a true exposure-response relationship if jobs are misclassified, the fiber counts are erroneous or irrelevant, or the range of cumulative fiber exposure among the workers is narrow. Synergetic effects from other exposures in parts of the study population may also obscure a true relationship.

The slight lung cancer excess that was seen in this study could theoretically be due to other occupational exposures, environmental factors, life-style factors, or chance.

The exposure-response analysis was based on the assumption that the lung cancer risk among exposed workers is proportional to the total number of inhaled fibers, as demonstrated for asbestos exposure and lung cancer (17). This assumption may not necessarily apply to MMVF, however. Other theories have also been presented (eg, the importance of total surface area) (18). The fiber size distribution determines the fiber deposition in the lung and the total fiber surface. The airborne mean fiber size differed between various job titles in the Swedish plants (19), but there is no information about the fiber size variability between jobs held in the past, and this alternative model could not be tested.

Workers employed short-term (1—<2 years) had no increased lung cancer risk for either rock wool (SIR 69) or glass wool (SIR 72), while rock wool workers employed 2—9 years had the highest incidence rate (SIR 212) although it was not significantly increased. This excess may have been due to chance. In the European study (2) the workers employed <1 year had about the same lung cancer risk as workers employed 1—4 years.

An excess risk for deaths from external causes may indicate differences in, for example, life-style factors (alcohol, tobacco) between the observed workers and the general population. The observed excess risk for death from external causes (accidents, poisonings, and violence) in the glass wool plant was however due to five excess suicides among the women employed less than two years, while the excess risk in the rock wool plants was found among those employed 2—9 years.

Among the rock wool workers, a slight excess of incident lung cancer cases was found for those with 2—9 years of employment, and no such excess appeared for those employed less than two years. When the small size of the groups was taken into account, this finding did not support the assumption that short-term employment per se is associated with a life-style leading to an excess of lung cancer.

No smoking data were available in this study, but large differences in smoking habits are required to increase the risk for lung cancer substantially (20). Uncontrolled confounding from tobacco smoking may have contributed to the lung cancer excess among the medium-exposed workers, but it can hardly explain the lack of an exposure-response relationship.

There was no excess of liver cirrhosis. Therefore the average alcohol consumption of the mineral wool workers was approximately similar to that of the general population.

This study had too few lung cancer cases (N = 27) and stomach cancer cases (N = 19) to allow more general conclusions regarding the lung cancer and stomach cancer hazards from exposure to MMVF. The expected numbers in each exposure stratum were low, and the distribution of fibers per milliliter per year was narrow in the rock wool exposure-response analysis. The large European study will provide more precise estimations of risks associated with work in the MMVF production factories and the possible relationship between exposure to mineral fibers and lung and stomach cancer risk.

A case-referent study of lung cancer within the European cohort is also being planned. Its objective will be to explore further the importance of inhaled MMVF, and the contribution of nonoccupational factors or confounding factors such as other occupational exposures at the plants.

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