

Mortality of workers in a German rock-wool factory — A second look with extended follow-up

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CLAUDE J, FRENTZEL-BEYME R. Mortality of workers in a German rock-wool factory — A second look with extended follow-up. *Scand J Work Environ Health* 12 (1986): suppl 1, 53–60. A cohort of 2 092 workers employed in a German rock-wool factory was followed until the end of 1982, and the mortality experience was compared with the national mortality rates and the rates of an internal reference cohort. This mortality analysis revealed a standardized mortality ratio (SMR) of 110 for overall mortality. Significantly more malignant neoplasms occurred than were expected (SMR 127). The increase in risk for lung cancer (SMR 121), which was not statistically significant, was also not related to time since first exposure or length of employment. The occurrence of an unusually high SMR of 336 for benign and unspecified neoplasms could not be clarified. Most of the excess from other specific causes of death, such as stomach cancer, pancreatic cancer, and alcoholism, appear to be unrelated to the rock-wool production since they occurred either among workers employed for very short periods (less than one year) or as frequently among workers in the reference cohort.

Key terms: cancer, follow-up study, internal reference, man-made mineral fibers, mortality.

This communication concerns the findings of the extended follow-up of workers employed in a German rock-wool factory. The study was carried out in conjunction with the extension of the historical follow-up, until 1982, of a cohort of European man-made mineral fiber (MMMF) production workers carried out under the coordination of the International Agency for Research on Cancer (IARC).

Subjects and methods

As reported earlier (4), the study population comprised all workers employed in rock-wool production, packing, shipping, and maintenance activities ascertained through the available company payroll listings. The factory-based reference group was obtained by the same procedure and was also followed until the end of 1982. This group consisted of workers employed in the other production processes (mainly cork and styropor panel production) within the company premises so that occasional exposure to low levels of MMMF cannot be excluded. Coal tar, silica, urethane formaldehyde foam, and polystyrene were used some time during these production processes. Limited to male employees, the total size of the exposed and reference groups (2 092 versus 1 775) changed slightly due to errors in coding sex. As a result of the historical environmental investigation conducted by the Institute

of Occupational Medicine, Edinburgh, during 1983–1984 (2), rock-wool production was established as beginning in 1941 so that person-years at risk of dying were calculated from the first date of employment or 10 January 1941, whichever came later.

For the years 1952 to 1982 age-, sex-, calendar-time-, and cause-specific mortality rates of the Federal Republic of Germany from the mortality data bank of the World Health Organization, coded by A groups, were used for the calculation of expected deaths. The 1952 reference rates were applied to the person-years accumulated prior to the availability of the rates.

Local mortality rates from the Federal State of Rhineland Palatinate would have been desirable as reference rates since the area is representative of the area from which employees were drawn. Unfortunately the mortality rates were only available as of 1970. Any higher expected number of deaths derived from these rates for the overall observation period could then reflect either a real higher cause-specific mortality of the regional population or an increasing trend of mortality in the past 30 years, which would result in a more conservative estimate of risk. Alternatively, cause-specific adjustment factors based on local mortality rates could be used to derive a locally adjusted standardized mortality ratio (SMR). Since most of these adjustment factors were below 1.1, we preferred to use expected numbers and report SMR values based on the national mortality rates.

A modified life-table procedure was used to obtain person-years at risk and expected numbers of deaths on the basis of the national reference rates by five-year age groups and five-year calendar-time periods. SMR values between observed and expected deaths multiplied by 100 were calculated, and exact 95 % con-

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Table 1. Characteristics of the exposed and reference groups.

	Exposed group		Reference group		Total number
	N	%	N	%	
Persons	2 092	100	1 775	100	3 867
Alive	1 564	74.8	1 300	73.2	2 864
Dead	315	15.1	290	16.3	605
Lost to follow-up	97	4.6	118	6.7	215
Emigrated	116	5.5	67	3.8	183
Germans	1 839	87.9	1 594	89.8	3 433
Migrant workers	253	12.1	181	10.2	434
Person-years at risk	38 697		33 229		71 926

Table 2. Person-years for mortality by length of employment and follow up.

Length of employment (years)	Years since first exposure				Total
	≤9	10–19	20–29	≥30	
<1	8 158	4 020	1 334	44	13 556
1–4	6 376	2 439	1 075	94	9 984
5–9	3 769	1 475	796	117	6 156
10–19	—	5 034	1 123	170	6 326
≥20	—	—	2 149	525	2 674
Total	18 303	12 968	6 476	950	38 697

fidence limits (95 % CL) according to Miettinen were computed (12).

Due to the legislation on data protection and the fact that in some municipalities death certificates are only kept for 5 or 10 years, death certificates were not available for 7 % of those known to be dead. In order to reduce the number of unknown causes, the diagnosis was obtained from the last attending physician or next-of-kin, whoever responded. A previous study has shown that for cancer the validity of this information as the underlying cause of death on the death certificate is high (3). A separate mortality analysis was performed using these additional cause-specific number of deaths to reveal potentially important changes in the SMR.

The historical environmental investigation provided us with information on the use of binders in MMMF production. In the German factory, mineral oil was used as a binder from the very beginning. After 1953 resin binders were added, a measure which might have caused a change in the exposure conditions. Therefore it was deemed informative to look at those workers entering before and after 1953 separately.

An internal comparison with the reference group was carried out. Relative risks (RR) were estimated for causes of death with at least five observed deaths in one group, employing Miettinen's rate ratio estimate (8). Stratification by 10-year age groups was performed for causes of death with large numbers. Otherwise 25-year age groups were used in order to avoid strata with zero observed. Ninety-five percent

test-based confidence limits were calculated from the point estimate with the use of the standard normal deviate.

Results

The total numbers of death, persons lost to follow-up, and persons having emigrated are presented in table 1. The proportion of persons lost to follow-up and having emigrated was relatively large, 62 % of which being migrant workers.

Person-years at risk by duration of employment and years of follow-up of the exposed group are shown in table 2. Although the overall person-years were substantially large, one-third of the contribution came from persons with less than one year of employment. Person-years observed 20 to 29 years or 30 years or more since first exposure represented 16.7 and 2.5 % of the total, respectively.

The observed and expected numbers for selected causes of death are presented in table 3. The mortality from all causes was increased (SMR 110) with borderline significance. Malignant neoplasms occurred significantly more frequently than expected (SMR 127), but the excess of lung cancer (SMR 121) was not statistically significant. An unusually high SMR of 336 for benign and unspecified neoplasms [code 210–239 in the International Classification of Diseases (ICD)] was an observation singular to the German factory. These causes of death included eight neoplasms of unspecified nature of the brain and nervous system (ICD 238), one neoplasm of unspecified nature of the digestive organs (ICD 230), and one neoplasm of unspecified nature of other and unspecified organs (ICD 239).

The other two groups of causes of death showing borderline significance were mental disorders (ICD 290–315) and violent causes (ICD E800–E999). Alcoholic psychosis and alcoholism contributed to the former group entirely, reflecting perhaps a particular group of workers with a rather low socioeconomic status.

The 22 cases of deaths for which no death certificates were available resulted in an apparently high SMR for the group of symptoms and ill-defined conditions. Through communications with the last attending physicians and the next-of-kin, cause of death for an additional seven and five persons, respectively, were attained and used as substitute information. In table 3 the observed deaths after the inclusion of these additional cases are shown in parentheses to illustrate the amount of additional information.

With the use of these numbers to calculate the SMR values, changes in the results are seen for violent causes of death (SMR 143, 95 % CL 110–184) and the group of other malignant neoplasms (SMR 151, 95 % CL 99–221). Despite these differences the information derived solely from the death certificates has been used for further mortality analysis because of the

comparability of the source of information to that of the national statistics.

Since those employed for less than one year contributed to a third of the total person-years at risk, it is probable that the mortality of the entire cohort was influenced by this group. The mortality analysis of workers employed less than one year showed that, although overall mortality was significantly increased (SMR 140, 95 % CL 113–173), this excess was not attributable to any particular cause of death. This result could have been partly due to the large numbers of deaths with unknown causes (14 observed versus 2 expected). Nevertheless significant SMR values were found for mental disorders (alcoholism) with 4 observed and 1 expected, esophageal cancer with 2 observed and 0.3 expected, and unspecified neoplasms with 3 observed and 0.7 expected. Whereas the SMR for all malignant neoplasms was 137, the SMR for lung cancer was 62 (2 observed versus 3.3 expected).

Therefore, when those employed for less than one year were excluded, within the group employed for more than one year, the overall SMR was 102. Except for lung cancer (SMR 134, 19 observed versus 14.1 expected), the SMR values for most of the other specific causes were closer to 100.

The excess in mortality from malignant neoplasms in the entire cohort was related neither to time since first exposure (table 4) nor to duration of employment (table 5). The main contributions were made by lung cancer and stomach cancer, for which no apparent relationship to either time since first exposure or duration of employment was observed. For neoplasms of benign and unspecified nature, the highest SMR was found 0–9 years since first exposure (SMR 576); however, no case occurred 30 years or more after first exposure. On the other hand, an excess of deaths was observed equally among workers with various lengths of employment.

Table 3. Mortality analysis for the exposed group up to the end of 1982 (production and maintenance workers).

Cause of death ^a	Observed ^b	Expected	Standardized mortality ratio ^b	95 % confidence interval
Infective and parasitic diseases (000–136)	3	6.3	48	12–131
All malignant neoplasms (140–209)	80 (83)	63.1	127* (132*)	101–157
Buccal cavity and pharynx (140–149)	1	1.2	84	4–414
Esophagus (150)	3	1.3	224	57–612
Stomach (151)	13 (14)	9.7	134 (144)	75–223
Intestine, except rectum (152, 153)	4	4.1	98	31–236
Rectum (154)	4	2.9	137	44–331
Larynx (161)	2	0.9	229	38–757
Trachea, bronchus and lung (162)	21	17.4	121	77–181
Bone (170)	—	0.6	0	0–499
Prostate (185)	4	3.1	128	41–308
Bladder (188)	4	1.6	255	81–615
Leukemia (204–207)	2	2.2	93	16–307
Other lymphatic and hematopoietic neoplasms (200–203, 208–209)	—	2.5	0	0–150
Other malignant neoplasms ^c	22 (24)	15.9	139 (151)	89–207
Benign and neoplasms of unspecified nature (210–239)	10	3.0	336*	171–600
Endocrine, nutritional and metabolic diseases (240–279)	3	6.3	48	12–131
Mental disorders (290–315)	7	3.1	228*	100–452
Nervous system and sense organs (320–389)	8	10.6	76	35–144
Circulatory system (390–459)	89 (91)	98.4	90 (91)	73–111
Respiratory system (460–519)	13	16.7	78	43–130
Digestive system (520–577)	25 (27)	23.6	106 (115)	70–154
Genitourinary system (580–629)	1 (2)	5.5	18* (36)	1–90
Congenital anomalies (740–759)	1	0.4	268	14–1318
Symptoms and ill-defined conditions (780–796)	23 (11)	8.6	268* (128)	174–397
Accidents, poisonings and violence (E800–E999)	52 (56)	39.8	131 (143*)	98–170
Suicide (E950–E959)	19	13.5	141	88–216
All causes (000–999)	315	286	110	98–123

^a Code of the International Classification of Diseases, eighth revision, in parentheses.

^b "Extra" cases from ICD-796 with additional information on cause of death in parentheses.

^c Including six (seven) cases of neoplasms of the pancreas, two of the liver, one of the gallbladder, (one) of the testis, two of nonspecific urinary organs, one of other parts of the nervous system, one of the thyroid, and nine of other and unspecified sites.

* $p < 0.05$.

Table 4. Mortality analysis by time since first exposure for the exposed group up to the end of 1982 (production and maintenance workers). (O = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio 95 % CI = 95 % confidence interval)

Years since first exposure	O	E	SMR	95 % CI
<i>Deaths from all causes (000–999)^a</i>				
≤9	63	59.7	105	82–134
10–19	108	93.3	116	95–139
20–29	113	98.9	114	95–137
≥30	31	34.1	91	63–127
Total	315	286.0	110	98–123
<i>Deaths from all malignant neoplasms (140–209)^a</i>				
≤9	6	10.0	60	24–125
10–19	26	20.6	126	84–182
20–29	39	24.3	161*	116–217
≥30	9	8.1	111	54–203
Total	80	63.1	127*	101–157
<i>Deaths from stomach cancer (151)^a</i>				
≤9	—	1.8	0	0–210
10–19	5	3.4	147	54–325
20–29	7	3.4	204	89–404
≥30	1	1.1	91	5–450
Total	13	9.7	134	75–223
<i>Deaths from lung cancer (162)^a</i>				
≤9	2	2.2	90	15–297
10–19	9	5.8	157	76–287
20–29	8	7.2	112	52–213
≥30	2	2.3	89	15–293
Total	21	17.4	121	77–181
<i>Deaths from benign and unspecified neoplasms (210–239)^a</i>				
≤9	4	0.7	576*	184–1388
10–19	3	1.0	298	76–811
20–29	3	1.0	311	80–847
≥30	—	0.3	0	0–1182
Total	10	3.0	336*	171–600
<i>Deaths from diseases of the respiratory system (460–519)^a</i>				
≤9	1	2.4	42	2–206
10–19	4	5.1	78	25–188
20–29	5	6.4	78	29–173
≥30	3	2.7	110	28–300
Total	13	16.7	78	43–130

^a Code of the International Classification of Diseases, eighth revision, in parentheses.

* $p < 0.05$.

After the groups were separated by date of entry before and after 1953 (when resin binders were introduced to the production process), the excess in overall mortality was concentrated in the latter period with an SMR of 118 (table 6). It should be noted that there were no person-years at risk observed 30 years or more after first exposure for those entering after 1953 and that no deaths could have occurred in this category. Contrary to those from all causes, the deaths from malignant neoplasms were fairly evenly distributed among the two time periods. On the other hand, for both lung cancer and stomach cancer, the SMR values were increased only for those entering before 1953 (SMR 138 and 155, respectively), while, for those entering after 1953, the SMR values were around 100

Table 5. Mortality analysis by length of employment. (O = observed number of deaths, E = expected number of deaths, SMR = standardized mortality ratio, 95 % CI = 95 % confidence interval)

Length of employment (years)	O	E	SMR	95 % CI
<i>Deaths from all malignant neoplasms (140–209)^a</i>				
<1	16	12.5	128	73–209
1–4	9	10.1	89	41–168
5–9	11	7.7	144	72–257
10–19	27	20.5	132	87–192
≥20	17	12.4	137	80–219
<i>Deaths from stomach cancer (151)^a</i>				
<1	3	1.7	182	37–531
1–4	—	1.5	0	0–244
5–9	—	1.3	0	0–286
10–19	5	3.4	146	47–341
≥20	5	1.7	292	95–682
<i>Deaths from lung cancer (162)^a</i>				
<1	2	3.2	62	7–223
1–4	2	2.6	76	9–274
5–9	4	2.0	198	54–506
10–19	9	5.8	156	72–297
≥20	4	3.8	106	29–272
<i>Deaths from benign and unspecified neoplasms (210–239)^a</i>				
<1	3	0.7	450	93–1316
1–4	2	0.6	363	44–1311
5–9	1	0.4	246	6–1372
10–19	2	0.9	231	28–834
≥20	2	0.5	418	51–1511

^a Code of the International Classification of Diseases, eighth revision, in parentheses.

(SMR 100 and 103, respectively). An excess of deaths from unspecified neoplasms occurred in both periods (SMR 406 and 267, respectively).

When the exposed group was broken down by job title, the production workers had a lower overall mortality than the maintenance workers (table 7). The excess from malignant neoplasms and unspecified neoplasms was evenly distributed between the two groups, and the SMR values for the latter cause were statistically significant. Lung cancer mortality was higher among the maintenance workers, for whom the SMR was significantly increased 20–29 years after the first exposure, whereas the production workers showed a higher stomach cancer mortality. An additional case of stomach cancer was also reported for a production worker by the last attending physician.

The mortality analysis of the reference group revealed an SMR of 122 for overall mortality. A significant excess in mortality was observed for stomach cancer (SMR 216), mental disorders (SMR 259) (also attributed to alcoholism and alcoholic psychosis), and diseases of the circulatory system (SMR 131). There were also 16 cases of death for which no death certificate was available, and additional information was obtained for nine cases.

Since the exposed and reference groups were both wage-earning working populations, employed by the

Table 6. Mortality analysis for the exposed group by time since first exposure and date of entry.

Years since first exposure	Date of entry					
	1941—1953			After 1953		
	Observed	Expected	Standardized mortality ratio	Observed	Expected	Standardized mortality ratio
<i>Deaths from all causes (000—999)^a</i>						
≤9	11	17.5	63	52	42.3	123
10—19	38	35.8	106	70	57.8	122
20—29	72	60.9	118	41	38.0	108
≥30	31	34.1	91	.	.	.
Total	152	148.3	102	163	137.7	118*
<i>Deaths from all malignant neoplasms (140—209)^a</i>						
≤9	1	3.1	32	5	6.9	72
10—19	10	8.0	125	16	12.7	126
20—29	24	14.5	165*	15	9.7	154
≥30	9	8.1	111	.	.	.
Total	44	33.7	130	36	29.4	123
<i>Deaths from stomach cancer (151)^a</i>						
≤9	—	0.7	0	0	1.0	0
10—19	2	1.7	120	3	1.7	173
20—29	6	2.3	261*	1	1.1	89
≥30	1	1.1	91	.	.	.
Total	9	5.8	155	4	3.9	103
<i>Deaths from lung cancer (162)^a</i>						
≤9	—	0.7	0	2	1.5	132
10—19	6	2.2	272*	3	3.5	85
20—29	5	4.2	118	3	2.9	102
≥30	2	2.3	89	.	.	.
Total	13	9.4	138	8	8.0	100
<i>Deaths from benign and unspecified neoplasms (210—239)^a</i>						
≤9	2	0.2	888*	2	0.5	426
10—19	2	0.4	532	1	0.6	158
20—29	2	0.6	352	1	0.4	251
≥30	—	0.3	0	.	.	.
Total	6	1.5	406*	4	1.5	267

^a Code of the International Classification of Diseases, eighth revision, in parentheses.* $p < 0.05$.

same company but involved in different production processes, a comparison of their mortality would control for socioeconomic status and the healthy worker effect. As seen in table 8, there was no significant departure from 1.00 in the relative risks for selected causes of death except for neoplasms of the pancreas (RR 6.8) and of unspecified nature (RR 2.89, 95 % CL 1.14—7.32). Seven deaths from carcinoma of the pancreas were found exclusively among the exposed group. For neoplasms of unspecified nature 10 cases were observed in the exposed group, whereas only one was seen among the reference group.

Discussion

The mortality analysis of persons engaged in rock-wool production, packing, and maintenance work, followed until the end of 1982, showed increased risks of dying from malignant neoplasms (SMR 127), benign and unspecified neoplasms (SMR 336), and mental disorders

(SMR 228). The excesses in these three groups of causes of death were mainly due to stomach and lung cancer, neoplasms of unspecified nature of the brain and nervous system, and alcoholism and alcoholic psychoses.

The question arises as to whether these increased risks can be attributed to the occupational exposure in a rock-wool production plant. The carcinogenic potential of MMMF was recognized when animal experiments showed that mineral fibers administered intrapleurally or intraperitoneally can induce mesotheliomas (5, 10, 16). Epidemiologic studies on humans have reported inconsistent results with respect to an excess of lung cancer and nonmalignant respiratory diseases (1, 6, 9, 11, 13, 14). Therefore, emphasis has been placed on a search for an increased risk of lung cancer, non-malignant respiratory diseases, and mesothelioma.

The size of our cohort would have allowed us to detect with 0.9 probability a relative risk of about 2.0 for lung cancer. The finding of an increase in risk of 1.2 for lung cancer (21 observed versus 17.4 expected), which was not statistically significant, was also not related to time since first exposure or dura-

Table 7. Mortality analysis by time since first exposure for the production workers and the maintenance workers up to the end of 1982.

Years since first exposure	Production			Maintenance		
	Observed	Expected	Standardized mortality ratio	Observed	Expected	Standardized mortality ratio
<i>Deaths from all causes (000—999)^a</i>						
≤9	44	38.8	113	19	20.9	91
10—19	65	59.3	110	43	34.0	126
20—29	70	65.8	106	43	33.1	130
≥30	19	20.9	91	12	13.2	91
Total	198	184.7	107	117	101.3	116
<i>Deaths from all malignant neoplasms (140—209)^a</i>						
≤9	4	6.6	61	2	3.5	57
10—19	10	13.1	122	10	7.5	133
20—29	25	16.2	142	16	8.1	197*
≥30	7	4.9	143	2	3.2	62
Total	50	40.7	123	30	22.4	134
<i>Deaths from stomach cancer (151)^a</i>						
≤9	—	1.2	0	—	0.6	0
10—19	3	2.2	137	2	1.2	165
20—29	5	2.3	219	2	1.2	174
≥30	1	0.7	151	—	0.4	0
Total	9	6.3	143	4	3.4	118
<i>Deaths from lung cancer (162)^a</i>						
≤9	1	1.4	70	1	0.8	126
10—19	6	3.6	166	3	2.1	141
20—29	2	4.8	42	6	2.4	249*
≥30	1	1.3	75	1	0.9	108
Total	10	11.1	90	11	6.3	176
<i>Deaths from benign and unspecified neoplasms (210—239)^a</i>						
≤9	3	0.5	666*	1	0.2	410
10—19	2	0.6	312	1	0.4	272
20—29	1	0.6	156	2	0.3	618*
≥30	—	0.2	0	—	0.1	0
Total	6	1.9	313*	4	1.1	379*
<i>Deaths from diseases of the respiratory system (460—519)^a</i>						
≤9	1	1.6	64	—	0.8	0
10—19	4	3.2	124	—	1.9	0
20—29	4	4.2	95	1	2.2	46
≥30	2	1.7	119	1	1.0	96
Total	11	10.7	103	2	6.0	34

^a Code of the International Classification of Diseases, eighth revision, in parentheses.

* $p < 0.05$.

tion of employment. However, an increased SMR was found for those entering before 1953 but not for those entering after 1953. The 13 deaths from diseases of the respiratory system were less than the 16.7 expected deaths, and not a single case of mesothelioma was found.

An increased mortality from stomach cancer could have led to speculation about an effect of fibers entering the digestive tract. But the fact that in the reference group the SMR of stomach cancer was significantly increased points to some similar occupational exposures within the company grounds (not exclusively MMMF) and/or to risk factors prevalent among both groups and their origin, such as a lower socioeconomic class. Since the excess was concentrated in the exposed group among those workers entering before 1953 (SMR 155 versus SMR 103 for after 1953) but among those

entering after 1953 in the reference group (SMR 342 versus SMR 57 for before 1953), still different factors could have been involved in the incidence of stomach cancers of these two groups.

Similarly the occurrence of mental disorders (specifically alcoholism and alcoholic psychosis) was above that expected from the general population in both the exposed and reference groups. Since four of the seven cases in each of the two groups were employed for less than a year, the excess mortality would unlikely have been related to the occupational exposure, but rather reflects the type of workers (from a lower class) who enrolled for jobs involving hard work and a dusty environment and who possibly frequently changed employers.

More unusual are the increased risks of dying from neoplasms of unspecified nature (in particular of the

Table 8. Relative risks of selected causes of death for the total period of observation.

Cause of death ^a	Number of deaths ^b		Relative risk	95 % Confidence interval
	Exposed group	Reference group		
All causes (000—999)	315	290	0.86 ^c	0.68—1.10
Infective and parasitic diseases (000—136)	3	6	0.26	0.03—2.43
All malignant neoplasms (140—209)	83	68	1.03 ^c	0.67—1.57
Esophagus (150)	3	—	2.49	0.45—13.83
Stomach (151)	14	17	0.65	0.27—1.55
Intestine except rectum (152, 153)	4	5	0.81	0.40—1.64
Rectum (154)	4	5	0.40	0.02—9.29
Pancreas (157)	7	—	6.76*	1.01—45.20
Bronchus and lung (162)	21	16	1.41	0.17—11.73
Neoplasms of unspecified nature (230—239)	10	1	2.89*	1.14—7.32
Mental disorders (290—315)	7	7	0.62	0.02—16.21
Nervous system and sense organs (320—389)	8	1	6.28	0.90—43.86
Circulatory system (390—459)	90	110	0.74 ^c	0.60—0.92
Respiratory system (460—519)	13	14	0.41	0.02—7.76
Digestive system (520—577)	27	29	0.70	0.29—1.65
Symptoms and ill-defined conditions (780—796)	11	8	1.07	0.53—2.81
Accidents, poisonings and violence (E800—E999)	57	40	1.14	0.88—1.46

^a Code of the International Classification of Diseases, eighth revision, in parentheses.

^b Including additional cause of death information from physicians and next-of-kin.

^c Stratified by 10-year age groups; otherwise stratified by 25-year age groups.

* $p < 0.05$.

brain and nervous system) and pancreatic cancer in the exposed group. Since one case of neoplasm of unspecified nature of the digestive tract and no carcinoma of the pancreas was found in the reference group, the mortality from these causes appears to be particular to the exposed group. Of the seven cases of pancreatic cancer (one of them ascertained through the last attending physician), however, four men were employed for one month only and another one worked in the factory for less than one year so that, here again, no association with exposure in rock-wool production is conceivable.

On the other hand, although the excess mortality from neoplasms of unspecified nature was related neither to time since first exposure nor to the duration of employment (tables 4 and 5), it cannot be excluded that the increased risk may have been partly related to exposures within the company.

As mentioned in our previous communication (4), the interpretation of any positive findings may be complicated by the possibility of mixed exposure to asbestos, silica, formaldehyde, ammonia, oil binders, and coal tar present in the environment of the workers. In addition, since 43 % of the workers were employed for less than one year, previous occupational exposures on which no information was available could have also played an important role.

Our estimates of the SMR values for specific causes of death may still be conservative due to the inclusion of migrant workers who only had an apparently low overall mortality (SMR 49, 3 observed versus 6.2 ex-

pected) compared to that of the general population. According to earlier observations, migrant workers often leave for their native country before death (7). In addition, the inavailability of death certificates for 7 % of the total deaths has led to lower observed numbers for specific causes of death.

Conclusion

The results of our study are nevertheless consistent with the findings of the collaborative study (15) in which an elevated mortality for lung cancer was found among rock-wool workers employed during the early technological phase of this process. Since oil binders were used from the beginning in German rock-wool production, none of the workers were exposed to the environment being designated as the "early technological phase." Hence, unlike the findings in some of the other factories, no significantly increased mortality for lung cancer was observed among our study cohort. Most of the excess from other specific causes of death appear to be unrelated to the rock-wool production since they occurred either among workers employed for very short periods or as frequently among workers in the reference group.

Thus the evidence from this study indicates some adverse health effects from being ever employed in rock-wool production, but it appears difficult to relate these causally to exposure to MMMF.

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