

Mortality study of workers in the man-made mineral fiber production industry in the United Kingdom

by Martin J Gardner, PhD,¹ Paul D Winter, MSc,¹ Brian Pannett, MSc,¹ Marion JC Simpson,² Carol Hamilton, BSc,¹ E Donald Acheson, DM^{1,3}

GARDNER MJ, WINTER PD, PANNETT B, SIMPSON MJC, HAMILTON C, ACHESON ED. Mortality study of workers in the man-made mineral fiber production industry in the United Kingdom. *Scand J Work Environ Health* 12 (1986): suppl 1, 85–93. The workforces of two factories in the United Kingdom have been followed up to the end of 1984 as part of the collaborative European study of the health of workers in the man-made mineral fiber industry. In the cohort from an English glass-wool plant there was no suggestion of any excess mortality compared to national or local rates, except for lung cancer among men in comparison to the national level. However, the data indicate that the workers were largely local persons by place of birth, occupation, and death, and they therefore suggest that the national comparison was inappropriate. Lung cancer mortality showed little relationship to length of employment, duration of time since first exposure, occupational classification, or level of exposure. In the cohort from a continuous-filament plant in Northern Ireland no excess mortality from cancer was found. There were, however, raised death rates from violent causes and cardiovascular disease, but these rates were not exceptional for the area of the country in which the factory was located. No deaths from mesothelioma were reported in either cohort.

Key terms: glass wool, continuous filament, follow-up study, cancer.

The collaborative epidemiologic study of the health of workers in the European man-made mineral fiber industry, coordinated by the International Agency for Research on Cancer in conjunction with the Joint European Medical Research Board, was initiated in the late 1970s (2). The principal reason was the concern that man-made mineral fibers may have effects on human health similar to those of asbestos (9, 11), since it had been demonstrated that man-made mineral fibers (including glass) of the appropriate configuration could produce pleural tumors, resembling human mesenchymal mesotheliomas, when implanted in the pleural cavities of animals (19, 20). Inhalation studies with animals have not, however, indicated a carcinogenic effect — a review of the experimental evidence is included in this volume (4). Findings from the first mortality follow-up to 1977 in all the European centers combined have been published previously (17), and those from a further follow-up to the end of 1982 are included in this volume (18).

Among the 13 factories from the seven different countries included in the study, two are from the United

Kingdom. One of these is a factory in England which produces glass wool, and the second a factory in Northern Ireland which has produced continuous glass filament in the past. With the cooperation of the two factories concerned, arrangements were made in 1979 for the extraction of information on all individuals employed between the start of production and the end of 1978. For the purposes of this report on these two factories we have been able to extend the period of follow-up to the end of 1984.

Materials and methods

Factory in England

Production. The factory started operation in 1943 and is still manufacturing glass fiber. The main product has been glass wool in the form of rolls, slabs, and molded pipes. Other products made in significant amounts include staple tissue, staple yarns, continuous filament, and fiber for air filters and for aircraft insulation.

The Owens steam blowing process was used in the manufacture of glass wool of nominal fiber diameter (12–15 μm) from 1945–1962 and of staple tissue fiber of nominal diameter (11–13 μm) from 1948–1978. Between 1953 and 1980 the same process was employed to produce air filter fibers with nominal diameters of 20–30 μm and 1 000 μm . A slight variant of the same process was used between 1943 and 1958 for making staple fibers with nominal diameters of 8–10 μm . During the period 1949–1957 a flame attenuation process

¹ Environmental Epidemiology Unit of the Medical Research Council (University of Southampton), Southampton General Hospital, Southampton SO9 4XY, England.

² Department of Community Medicine, The Queen's University of Belfast, Belfast BT12 6BJ, Northern Ireland.

³ Present address: Department of Health and Social Security, Alexander Fleming House, Elephant and Castle, London SE1 6BY, England.

Reprint requests to: Professor MJ Gardner, MRC Environmental Epidemiology Unit, Southampton General Hospital, Southampton SO9 4XY, England.

was used for making fibers for aircraft insulation with nominal diameters (1–3 μm).

The TEL (derived from “laboratoire expérimental thermique”) rotary process was introduced in 1959 for the main glass-wool products, and by 1962 all glass-wool products had been converted to this process and had a nominal diameter of 7 μm . Molded pipe insulation was converted to this fiber in 1960, while in 1981 other modifications led to pipe insulation being produced with TEL fibers of nominal diameter (4–7 μm). During the period 1962–1968 the TEL process was used to produce fibers of nominal diameter (2–5 μm) for aircraft insulation.

Finally a mechanical drawing process was in operation between 1954 and 1970 for the production of continuous filaments with nominal diameter (9–13 μm).

These various fibers were used in the manufacture of several products, including mattresses and quilts, insulation boards, acoustic tiles, air filters, and coated yarns. General room ventilation has been used since 1943, with local exhaust ventilation installed at critical points. The extraction systems have been gradually improved, especially from 1970. More details of the history and activities of the factory can be found in the paper by Cherrie & Dodgson (3).

Workforce and follow-up study. Records on all individuals employed from April 1946 to 31 December 1978 were available from the salaries department of the company, and these data were used as the major source of information. The records of persons employed before April 1946 were incomplete in that workers who left the factory before that date were not identifiable. The data taken from the salaries department were supplemented and checked from the nominal and master rolls of the company, and from the pension and medical records. Workers employed for less than one year were excluded, mainly due to the limited personal information available because they did not qualify for a pension and partly because of their large number. Data on a total of 4 766 persons were abstracted from the various sources.

The study individuals were then identified, where possible, in the National Health Service Central Register at Southport, and we were provided with information on vital status and a copy of the death certificate if the person had died. The identified records in the Register were “flagged,” and on a continuing quarterly basis we have received details of any changes in status, including further death certificates.

Information on persons whose records could not be traced in the Register was sought from the Department of Health and Social Security office in Newcastle during 1979–1980 and again in 1985. For further deaths thus notified to us, death certificates were subsequently obtained through the National Health Service Central Register.

Factory in Northern Ireland

Production. The factory in Northern Ireland opened in 1946, producing glass yarns from continuous filaments using scrapped sheet glass and scrapped bottle glass as a feedstock. The plant continued to manufacture glass narrow tape, glass sleeving and cording, and glass broad tape from continuous filaments produced by the drawing process. During this early period, starch binders were used on all primary products. In 1954 the factory changed ownership, and the production of glass rove and glass rove-based cloth started. Production of glass filaments continued until September 1975, but weaving of fiber imported from another factory continued until 1980.

The filaments manufactured were made chiefly in three nominal diameters, namely, 9, 11, and 13 μm . Binders were used throughout, being combinations of polyvinyl acetate, starch, and vegetable oil. Secondary processes undertaken at this factory were heat cleaning and cloth finishing, 1960–1974 (without binder); roving and chopping, 1959–1975 (with binder); twisting and doubling, 1956–1975 (with binder); and cloth and tape weaving, 1956–1980 (with binder).

Ventilation systems were first installed in 1962 in the broad weaving department, followed by installment in the filament division in 1966. In 1968 further ventilation equipment was installed in the twisting and doubling and tape weaving departments. Further details are available in the paper by Cherrie & Dodgson (3).

Workforce and follow-up study. Records for all persons employed from 1956 to 31 December 1978 were readily available, either on job application forms (since 1956) or in personnel files (1963 on). For earlier years, medical records on all workers employed from 1955 and wages books in existence for the years 1946 to 1954 were used to try to complete the ascertainment of all persons who had ever worked in the factory. However, the earliest date of leaving employment at the factory that we have recorded for any individual is June 1957, which suggests that records of previous leavers have not been identified. Consequently we have excluded these early years from the mortality analysis. Data on a total of 1 943 persons were included from these sources.

The follow-up of the workforce to ascertain current vital status has been carried out with the assistance of the Central Services Agency in Belfast and with the aid of Dr TJF Campbell, who was the factory medical officer from 1955 until 1980, and coordinated by one of us (MJCS). Two major follow-up exercises were completed — the first during 1979–1980 and the second during 1984–1985.

The latter follow-up, of all members of the cohort who were not recorded as dead in 1979–1980, was carried out in the following way. Each individual's record

was searched for at the Central Services Agency, and those of persons who were found to be alive were "flagged" so that we have been informed of subsequent deaths as they are registered. For those individuals who were found at the Agency to have died, we obtained a copy of their death certificate from the General Register Office in Belfast. Persons who were not identified at the Agency were then traced where possible through Dr Campbell and/or their own general practitioner where we knew of the latter's identity from the factory records. For those still remaining untraced, because there was the possibility that they might be living in England, details were sent to the National Health Service Central Register and to the Department of Health and Social Security for further searches to be made.

Common information

Job categories and fiber exposure. Among the information abstracted from the records were dates of starting and leaving employment, together with descriptions of all recorded jobs carried out in the factories, including any changes of job. The detailed information on jobs was grouped into the following main categories for the purpose of the follow-up analysis: preproduction, production, secondary processes, secondary processes (less dusty), maintenance, general staff, and office workers. Secondary processes was just one group for the factory in Northern Ireland.

Short-term environmental surveys of dust levels in the factories were carried out by the Institute of Occupational Medicine (Edinburgh) during 1977 in England and during 1979 in Northern Ireland (13, 14, 15). Estimates of the degree of exposure to respirable and nonrespirable fibers were made in each factory. Samples were collected on membrane filters with personal monitors from representative groups of workers and analyzed by interference microscopy. Determinations were also made of mass concentrations of airborne dust, and samples were examined for fiber-size distribution and compositional analysis. Respirable fibers were defined as those of length (L) $\geq 5 \mu\text{m}$, diameter (D) $< 3 \mu\text{m}$, and aspect ratio (L:D) ≥ 3 .

The fiber levels were low with mean concentrations of less than 0.1 fibers/ml for each job category, and the levels were particularly low for the continuous-filament process in Northern Ireland. The mean respirable concentration was highest in the secondary processes category of the English factory at 0.073 fibers/ml, and also in the secondary process in Northern Ireland at 0.002 fibers/ml. The results for mean mass concentrations in the English factory ranged from 0.8 to 2.1 mg/m³ across the main categories, the highest level being found in the secondary processes category, as for the fiber concentration.

When these figures are being interpreted, it should be borne in mind that changes in methods of production and ventilation, which may have lowered respi-

rable fiber levels, took place within the factories during the period 1943–1977 and in 1979. The job coding and environmental surveys were completed in advance of any information becoming available from the mortality follow-up.

In addition, the historical development of each factory in the European study has been classified by the Institute of Occupational Medicine into three basic technological phases (3, 18). The "early" phase represents a period of batch processing and/or the absence of the use of dust-suppressing agents, and the "late" phase a period of use of modern mechanized production methods with oil and resin binders to suppress dust levels. The "middle" phase covered an intermediate period with mixed exposures to processes both with and without dust suppressors. This categorization did not apply to the factory producing continuous filament in Northern Ireland, which used starch binders from its start in 1946. In the English factory the middle phase started in 1945 with the application of bitumen binder, although oil was used previously, and the late phase started in 1968.

Mortality analysis. The start of follow-up was taken as 1 April 1946 or after one year of employment, whichever came later, for the English factory, and as 1 January 1956 for the factory in Northern Ireland. The end of follow-up for the purpose of this analysis was 31 December 1984, and, for individuals who had died, the underlying cause was taken from the death certificate. The numbers of observed deaths were compared to those expected on the basis of national rates for relevant calendar-year-, cause-, sex-, and age-specific groups. The expected numbers were calculated by the person-years method using a computer program (PYCL) adapted from that of Hill (10). Local adjustment factors were applied to the expected numbers for the English factory with the use of the available standardized mortality ratio (SMR) by cause during 1968–1978 for the area, St Helens County Borough, containing the factory (7, 8). Such figures were not available for local areas in Northern Ireland. Confidence intervals have been calculated by the usual methods based on the Poisson distribution.

Results

Factory in England

Table 1 shows the total number of individuals whose records were abstracted by sex and quality of the information available for the purposes of follow-up in the National Health Service Central Register and analysis. The number of men (N = 3 548) in the study was three times as great as the number of women (N = 1 186). The remaining 32 (0.7 %) persons had to be excluded due to missing information on date of

birth, sex, or date of starting employment at the factory.

The annual factory intake of persons who worked for more than one year was reasonably steady during 1946–1978 at about 110 men and 40 women. Of the 4 734 persons in the study cohort, 2 284 (48 %) stayed to complete at least five years of employment by the end of 1978 with similar proportions for men and women.

Table 1. Number of persons in the English factory for whom records were abstracted by quality of information and sex.

Quality of information	Number of persons	Percentage
Usable		
Men	3 548	74
Women	1 186	25
Not usable*		
Men	11	0.2
Women	14	0.3
Unknown	7	0.1
	32	0.7
Total	4 766	100

* Twenty-eight had missing "date of birth," seven missing "sex," and four missing "date of starting employment."

Table 2. Vital status at the end of 1984 by sex for the study cohort in the English factory.

Status on 31 December 1984	Men		Women	
	Number	Percent	Number	Percent
Alive	2 927	82	1 005	85
Dead	509	14	113	10
Emigrated	50	1.4	18	1.5
Lost to follow-up	62	1.7	50	4.2
Total	3 548	100	1 186	100

Table 2 shows the vital status of the 4 734 study individuals by sex as of 31 December 1984. Overall 3 932 (83 %) were traced to be still alive, and 622 (13 %) were found to have died. A small proportion (3.8 %) could not be followed to the end of the study period. Sixty-eight (1.4 %) of these persons had left the country, one (0.02 %) was known to be alive in 1980 at the Department of Health and Social Security but not traced in 1985, and 111 (2.3 %) could not be traced in the National Health Service Central Register or at the Department of Health and Social Security.

Tables 3 and 4 show the numbers of deaths from 1 April 1946 to the end of 1984 by sex for the main groups of causes, and a comparison with those expected on national rates for England and Wales. As well, the available local area SMR values for 1968–1978 are given for the large urbanized district of St Helens in which the factory is situated, together with adjusted comparisons. Of the total 622 deaths, 290 (47 %) occurred during 1968–1978, and of these 220 (76 %) took place in St Helens. Of the 88 deaths before 1968 there were 65 (74 %) in St Helens, and for the 244 deaths after 1978 the corresponding figure was 169 (69 %). Among the 506 deceased persons for whom we know the place of birth, because this information has been recorded on death certificates since 1969, 366 (72 %) were born locally in St Helens. Moreover, among the 506 deceased for whom we know the place of birth and death, 306 (60 %) were born and died in St Helens; another 81 (16 %) had these two events recorded within a five-mile (8-km) radius of the area.

For each sex the total number of deaths was similar to that expected at national rates, but lower than the local mortality figure. Among the separate causes of death there was a suggestion of raised mortality from lung cancer in the study cohort. However, a raised value was not found for men, among whom most of

Table 3. Mortality by cause of death among the male workforce of the English factory from 1 April 1946 to 31 December 1984.

Cause of death ^a	Number of deaths ^b		O:E	95 % confidence interval for O:E	Local area SMR ^c	O:E _L ^d
	O	E				
All malignant neoplasms (140–209)	140	134	1.05	0.88–1.23	115	0.91
Cancer of the stomach (151)	12	14	0.87	0.45–1.53	130	0.67
Cancer of the lung (162)	69	55	1.26	0.98–1.59	124	1.01
Cancers of other sites	59	65	0.90	0.69–1.16	104	0.87
All other causes	369	383	0.96	0.87–1.07	121	0.80
Circulatory diseases (390–458)	252	242	1.04	0.92–1.18	113	0.92
Respiratory diseases (460–519)	54	58	0.94	0.70–1.22	147	0.64
Accidents, poisoning and violence (E800–E999)	21	33	0.64	0.40–0.98	118	0.54
Other causes	42	51	0.83	0.60–1.12	122	0.68
All causes (000–999)	509	517	0.99	0.90–1.07	120	0.82

^a Code of the International Classification of Diseases, eighth revision (21), in parentheses.

^b O = observed deaths, E = expected deaths at cause-, calendar-year-, sex- and age-specific rates for England and Wales.

^c The standardized mortality ratio (SMR) values for the local area were based on mortality in St Helens County Borough during 1968–1978 (7, 8).

^d E_L = locally adjusted expected deaths = (E × local area SMR)/100. Confidence intervals for O:E_L can be found by dividing those given for O:E by the local area SMR/100.

the lung cancer deaths had occurred, when the comparison was with the local SMR of 124 for lung cancer among men during 1968–1978; the local SMR was based on the occurrence of 734 deaths. The adjusted observed:expected (O:E) ratio becomes 1.01 with a 95 % confidence interval of 0.79–1.28. There was also an excess mortality from stomach cancer among the women, but the figure was based on 6 deaths versus 2 expected and a high local SMR of 153. Mortality from nonmalignant respiratory disease was comparable to national levels for each sex but was much lower than the local rates.

Lung cancer mortality was examined in various other ways, but mainly for men since the numbers of deaths among women were small. Table 5 shows lung cancer rates for men by time since entry to employment and duration of employment. The O:E ratio was higher in the first 20 years after entry than in later years (1.38 versus 1.20). Similarly, there was little indication of a trend in lung cancer mortality with duration of employment — for those employed for more or less than five years the O:E ratios were 1.22 and 1.32, respectively.

Most of the employed persons (68 % of the men and 80 % of the women) had jobs in only one category during their period of work in the factory, and many of the remainder worked in only two categories (20 and

12 %, respectively). Table 6 shows lung cancer mortality according to the highest fiber exposure category in which individuals worked. As can be seen, there was a slight suggestion of higher mortality from lung cancer being associated with higher estimated exposure to respirable fibers, except for maintenance workers, but the 95 % confidence intervals were wide and there were no statistically significant differences.

A large number of persons, 3 240 (68 %), were first employed in this factory during the middle technological phase, and thus they dominate the results when looked at in this way. For both sexes combined 62 lung cancer deaths occurred among nonoffice workers entering during this phase compared to 46 expected (O:E = 1.36). The O:E ratios for the other two phases were based on much smaller figures — 1.04 (O = 2, E = 1.92) for the early phase and 1.28 (O = 9, E = 7.1) for the late phase — and no statistically important differences were evident.

Factory in Northern Ireland

Table 7 shows the total number of individuals for whom records were abstracted in Northern Ireland in the same manner as table 1 does for the English factory. Somewhat less than twice as many men (N = 1 196) as women (N = 714) had suitable information

Table 4. Mortality by cause of death among the female workforce of the English factory from 1 April 1946 to 31 December 1984.^a

Cause of death	Number of deaths		O:E	95 % confidence interval for O:E	Local area SMR	O:E _L
	O	E				
All malignant neoplasms (140–209)	41	37	1.11	0.80–1.51	104	1.07
Cancer of the stomach (151)	6	2	2.77	1.02–6.04	153	1.81
Cancer of the lung (162)	7	5	1.50	0.60–3.09	96	1.56
Cancers of other sites	28	30	0.93	0.62–1.34	99	0.94
All other causes	72	74	0.97	0.76–1.22	115	0.84
Circulatory diseases (390–458)	39	42	0.92	0.65–1.26	110	0.84
Respiratory diseases (460–519)	10	10	0.98	0.47–1.79	134	0.73
Accidents, poisoning and violence (E800–E999)	4	6	0.68	0.19–1.75	102	0.67
Other causes	19	16	1.19	0.72–1.86	122	0.98
All causes (000–999)	113	111	1.02	0.84–1.22	113	0.90

^a See the footnotes to table 3.

Table 5. Mortality from lung cancer to the end of 1984 among men (excluding office workers) in the English factory by duration of follow up and length of employment.^a

Length of employment (years)	Years since starting employment																Total			
	1—9				10—19				20—29				≥30							
	O	E	O:E	O:E _L	O	E	O:E	O:E _L	O	E	O:E	O:E _L	O	E	O:E	O:E _L	O	E	O:E	O:E _L
1—4	10	7.1	1.42	1.14	4	4.7	0.85	0.69	5	4.1	1.21	0.97	2	1.4	1.43	1.15	21	17.3	1.22	0.98
5—9	1	4.0	0.25	0.20	8	3.8	2.09	1.69	1	2.2	0.45	0.36	—	0.6	0.00	0.00	10	10.7	0.94	0.75
10—19	.	.	.	.	15	7.6	1.98	1.59	7	4.3	1.63	1.31	2	0.9	2.33	1.88	24	12.7	1.88	1.52
≥20	.	.	.	.	.	.	.	.	2	3.9	0.51	0.41	3	2.2	1.39	1.12	5	6.1	0.82	0.66
Unknown	—	0.5	0.00	0.00	2	1.4	1.45	1.17	4	1.5	2.69	2.17	—	0.4	0.00	0.00	6	3.8	1.60	1.29
Total	11	11.5	0.95	0.77	29	17.5	1.66	1.34	19	16.1	1.18	0.95	7	5.5	1.28	1.03	66	50.6	1.30	1.05

^a Table entries are observed deaths (O)/expected deaths (E), O:E and O:E_L ratios (see the footnotes to table 3).

Table 6. Mortality from lung cancer to the end of 1984 in the English factory by employment category of highest exposure to respirable fiber concentrations as measured in 1977.^a

Highest exposure category	Respirable fiber levels (fibers/ml)	Number of workers	Number of deaths		O:E	95 % confidence interval for O:E	O:E _L
			O	E			
<i>Men</i>							
Secondary processes	0.073	605	14	9.8	1.43	0.78— 2.40	1.15
Production	0.022	933	16	11.8	1.35	0.77— 2.20	1.09
General works	0.014	484	14	11.8	1.18	0.65— 1.98	0.95
Secondary process (less dusty)	0.008	305	3	2.9	1.04	0.22— 3.05	0.84
Maintenance	0.007	679	15	10.2	1.47	0.82— 2.42	1.18
Preproduction	0.005	5	—	0.1	0.00	0.00—25.62	0.00
Office workers	.	295	3	4.3	0.70	0.15— 2.06	0.57
Unknown	.	242	4	3.9	1.03	0.28— 2.65	0.83
<i>Women</i>							
Secondary processes	0.073	327	3	1.3	2.27	0.47— 6.63	2.36
Production	0.022	30	1	0.2	5.33	0.13—29.67	5.55
General works	0.014	146	2	0.8	2.38	0.29— 8.59	2.48
Secondary process (less dusty)	0.008	165	—	0.8	0.00	0.00— 4.50	0.00
Maintenance	0.007	56	1	0.2	6.76	0.17—37.66	7.04
Preproduction	0.005	5	—	0.0	0.00	0.00—104.5	0.00
Office workers	.	343	—	0.7	0.00	0.00— 5.34	0.00
Unknown	.	114	—	0.6	0.00	0.00— 5.92	0.00

^a See the footnotes to table 3.

Table 7. Number of persons in the factory in Northern Ireland for whom records were abstracted by quality of information and sex.

Quality of information	Number of persons	Percentage
Usable		
Men	1 196	62
Women	714	37
Not usable*		
Men	19	1.0
Women	8	0.4
Unknown	6	0.3
Total	1 943	100

* Twenty-four had missing "date of birth," six had missing "sex," and four had missing "date of starting employment."

Table 8. Vital status at the end of 1984 by sex for the study cohort in the factory in Northern Ireland.

Status on 31 December 1984	Men		Women	
	Number	Percent	Number	Percent
Alive ^a	833	70	544	76
CSA	704	59	465	65
NHSCR	48	4	33	5
DHSS	81	7	46	6
Dead	135	11	21	2.9
Lost to follow-up ^b	228	19	149	21
Alive GP	189	16	121	17
Alive FU1	22	1.8	17	2.4
Alive Eng	2	0.2	1	0.1
No trace	15	1.3	10	1.4
Total	1 196	100	714	100

^a According to the Central Services Agency (CSA), the National Health Service Central Register (NHSCR) or the Department of Health and Social Security (DHSS).

^b Alive GP = 310 persons known alive through their general practitioner as of 30 June 1984; alive FU1 = 39 persons traced alive at first follow-up, but not traced at second follow-up; alive Eng = three persons traced in England, but subsequently emigrated; no trace = 25 persons not traced at either first or second follow-up.

for inclusion in the study. The proportion (1.7 %) of records which did not contain adequate identifying information for purposes of follow-up was low.

In this factory the recruitment of new employees was greater during the 1960s than during other periods. The annual intake was about 60 men and 40 women during this decade compared to some 40 men and 20 women per year before and after these years. Of the total of 1 910 persons included in the cohort, only 521 (27 %) were known to have stayed in employment at the factory for more than five years up to the end of 1978, with similar proportions for men and women separately.

Table 8 shows the vital status of the study individuals by sex as of 31 December 1984. Overall 1 377 (72 %) were traced as alive and 156 (8 %) were found to have died. In addition to those recorded as alive by the Central Services Agency (61 %), the National Health Service Central Register (4 %), or the Department of Health and Social Security (7 %) at the end of 1984, a further 310 (16 %) were reported to be alive on 30 June 1984 through Dr Campbell or through the workers' general practitioners. Of the remainder, 39 (2 %) were found to be alive at the first follow-up, 3 (0.2 %) were traced in England at sometime but then emigrated, and 25 (1.3 %) could not be traced beyond the date of last known employment at the factory.

Table 9 and 10 give the numbers of deaths from 1 January 1956 to the end of 1984 for the main causes by sex, and a comparison with those expected according to national rates for Northern Ireland. As can be seen, mortality from all causes among men was raised by some 20 % in comparison with the figure expected, but this excess was not found for deaths from cancer. The number of lung cancer deaths was similar to that expected. The causes showing the largest increases for

Table 9. Mortality by cause of death among the male workforce of the factory in Northern Ireland from 1 January 1956 to 31 December 1984.

Cause of death ^a	Number of deaths ^b		O:E	95 % confidence interval for O:E
	O	E		
All malignant neoplasms (140—209)	24	25	0.97	0.62—1.45
Cancer of the lung (162)	9	8	1.19	0.55—2.27
Cancers of other sites	15	17	0.88	0.49—1.45
All other causes	112	89	1.25	1.03—1.51
Circulatory diseases (390—458)	64	52	1.24	0.95—1.58
Respiratory diseases (460—519)	7	10	0.71	0.28—1.45
Accidents poisoning and violence (E800—E999)	27	15	1.74	1.15—2.54
Other causes	14	12	1.15	0.63—1.92
All causes (000—999)	136	114	1.19	1.00—1.41

^a Code of the International Classification of Diseases, eighth revision (21), in parentheses.

^b O = observed deaths, E = expected deaths at cause-, calendar-year-, sex-, and age-specific rates for Northern Ireland.

Table 10. Mortality by cause of death among the female workforce of the factory in Northern Ireland from 1 January 1956 to 31 December 1984.

Cause of death ^a	Number of deaths ^b		O:E	95 % confidence interval for O:E
	O	E		
All malignant neoplasms (140—209)	9	12	0.77	0.36—1.48
Cancer of the lung (162)	—	1.3	0.00	0.00—2.93
Cancers of other sites	9	10	0.87	0.40—1.66
All other causes	12	21	0.57	0.30—1.01
Circulatory diseases (390—458)	7	10.3	0.68	0.27—1.40
Respiratory diseases (460—519)	—	2.6	0.00	0.00—1.42
Accidents poisoning and violence (E800—E999)	1	2.6	0.39	0.01—2.17
Other causes	4	5.2	0.77	0.21—1.97
All causes (000—999)	21	32	0.65	0.40—0.99

^a Code of the International Classification of Diseases, eighth revision (21), in parentheses.

^b O = observed deaths, E = expected deaths at cause-, calendar-year-, sex-, and age-specific rates for Northern Ireland.

male members of the cohort were accidents, poisoning and violence combined and circulatory diseases. Among women the mortality levels were generally much lower than expected at Northern Ireland rates, and no deaths from lung cancer had been reported.

When lung cancer mortality among men was looked at by duration since first exposure, length of employment, and occupational category, there were no suggestions of any relationships, although men who worked in the factory for less than one year had a high rate (O = 4, E = 1.1, O:E = 3.78). The numbers of men followed for more than 20 years since entry was small, and the lung cancer figures for this period were O = 1, E = 1.9, O:E = 0.53 compared to O = 8, E = 5.5, O:E = 1.45 for the first 20 years of follow-up. However, the numbers of deaths from lung cancer involved were small.

General experience

There have been no deaths from mesothelioma reported among the workforce of either the factory in England or that in Northern Ireland.

Discussion

This study of two factories in the United Kingdom is part of the European investigation of the health of the workforce of plants manufacturing man-made mineral fibers; the investigation as a whole is discussed elsewhere in this volume (18). However, there are specific points which can be made about the findings in the two United Kingdom factories.

Factory in England

One of the major diseases of interest a priori was cancer of the lung because of its strong relationship to asbestos. During the follow-up period there was an excess of 26 % of deaths among male members of the workforce in the English factory from this cause compared to rates in England and Wales. However, the local male death rate from lung cancer was also raised compared to the national level — by 24 % for the longest and central period during which figures were readily available. Although this time does not cover the total period of follow-up, some 45 % (31 out of

69) of the male lung cancer deaths among the cohort took place during these 11 years (1968–1978), during which the O:E ratio was 1.27 (O = 31, E = 24) — a value similar to the local SMR. During the period of follow-up before 1968 (ie, 1946–1967) the O:E ratio was 1.33 (O = 12, E = 9.0) compared to the SMR from lung cancer for men in St Helens of 110 during 1959–1963 (16). From published material (12) the SMR from lung cancer during 1980–1984 among men in St Helens can be determined to be 113 compared to the O:E ratio of 1.21 (O = 26, E = 21) in the cohort for 1979–1984. There is thus no suggestion of an increase over time, but it is noticeable that the SMR for St Helens was lower before and after the longest period of years available.

It is the practice in most follow-up studies of this kind to use national calendar-year-, cause-, sex-, and age-specific death rates as a first step in calculating expected numbers for making comparisons. This procedure is usually followed because possibly more appropriate regional (for example, county or district) rates are not available in the same detailed way. Nevertheless, neither national nor local rates are likely to be totally appropriate in any particular instance (6) — also in this study. The data on places of birth and of death available for this workforce suggest that they were largely local men with little long-distance migration and that the rates for St Helens are more relevant for comparative purposes. It is known that cigarette smoking has for many years been higher in urban than rural areas of England and Wales and that there is an associated marked urban/rural difference in lung cancer mortality in England and Wales (5).

The absence of any important relationships of the lung cancer rates internally within the cohort to such as duration of employment, job category in terms of estimated exposure levels, or time since first employment suggests also that the excess compared to England and Wales was not related in any major way, if at all, to employment in the factory. On the other hand the classification of jobs in this study, for purposes of collation with other European plants, has been less detailed than the information we have available from the factory records on the processes used and fiber types manufactured. We plan to examine these data further in a case-referent study.

There is no suggestion that any other cause of death has been raised among men in this cohort compared to national or local rates, including those such as digestive and other respiratory cancers which have been associated with asbestos in the past. Among women there was a slight excess of lung cancer deaths, but it was not statistically significant compared to local or national rates and was based on small numbers. The large O:E ratio of 2.77 for stomach cancer in women was decreased to 1.81 on adjustment by the local SMR (95 % confidence interval 0.67–3.95), which was statistically nonsignificant. The population of the area in which the factory is located has for many years had

high stomach cancer mortality, as evidenced by the two local SMR values of 130 for men and 153 for women during 1968–1978.

Factory in Northern Ireland

Among the workforce of the continuous filament factory in Northern Ireland during the follow-up period the number of lung cancer deaths was similar to that expected at the national rate among men and no such deaths occurred among women. There were no excesses of any other cancer for either sex, and the only raised mortality rates in the cohort were from accidents, poisoning and violence combined and from circulatory diseases among men.

In the former category of causes the main contribution to the excess was from deaths due to violence. This finding was not unexpected in this area, which is near the border with Eire and suffers a higher rate of violent deaths than other parts of Northern Ireland. The other raised cause of death, from circulatory diseases, was 24 % above the expected national figure. However, the Dungannon district council area of Northern Ireland, in which the factory was situated, had SMR values from ischemic heart disease [International Classification of Diseases (ICD) codes 410–414] of 109 and from cerebrovascular disease (ICD 430–438) of 129 among men during 1979–1981, and thus the cohort excess did not particularly differ from the local figure. Detailed rates by cause, including those from accidents, poisoning and violence, were not available for the district council area and thus could not be given in table 8.

Common discussion

In the joint European study an excess of lung cancer mortality was found among workers who had entered the industry during the early technological phase and who had been followed for more than 20 years — but after adjustment to local rates the raised mortality was apparent only for rock-wool production workers. Neither of the two collaborating factories in the United Kingdom produced rock wool. In addition the early phase before the introduction of dust-suppressing agents was short in the English factory — from 1943 to 1945 — and there was no such phase for the factory in Northern Ireland. The concentrations of airborne fibers measured in these factories during the late 1970s were low compared to the current control limit for chrysotile asbestos in the United Kingdom, and in the past would have probably been lower than in most asbestos operations.

The results given in this paper do not show any excess of lung cancer in workers with long follow-up. This occurrence is in agreement with the findings for the glass-wool and continuous-filament factories in the collaborative report (18), where the English factory

contributes most to the glass-wool experience and the factory in Northern Ireland is one of the two continuous-filament production plants. In contrast to the study of the other continuous fiber workforce, which showed raised mortality for cancer of the larynx (1), there were no deaths from this cause in the factory studied — but the statistical power to detect a raised risk was small, as the expected number of such deaths was only 0.38.

There have been no deaths from or registered cases of mesothelioma of the pleura or peritoneum among the members of either workforce.

Acknowledgments

We recognize that this study was made possible through the cooperation of the companies concerned, and we are grateful to their staff for help in many ways. We would like to acknowledge the roles of the Central Services Agency and the General Register Office in Belfast and of Dr TJF Campbell and many general practitioners in tracing persons from the factory in Northern Ireland, and of the National Health Service Central Register in Southport and the Department of Health and Social Security in Newcastle in tracing persons from both factories. We would like to thank the International Agency for Research on Cancer, Lyon, for their central organization and the Joint European Medical Research Board for their support. Finally, we are grateful to Ms B Grimes for preparing the typescript.

References

1. Bertazzi PA, Zocchetti C, Riboldi L, Pesatori A, Radice L, Latocca R. Cancer mortality of an Italian cohort of workers in man-made glass fiber production. *Scand J Work Environ Health* 12 (1986), suppl 1, 65—71.
2. Cameron JD. Man-made mineral fibres: Medical research — CIRFS/EURIMA initiative. *Ann Occup Hyg* 20 (1977) 149—152.
3. Cherrie J, Dodgson J. Past exposures to airborne fibers and other potential risk factors in the European man-made mineral fiber production industry. *Scand J Work Environ Health* 12 (1986): suppl 1, 26—33.
4. Davis JMG. A review of experimental evidence for the carcinogenicity of man-made vitreous fibers. *Scand J Work Environ Health* 12 (1986): suppl 1, 12—17.
5. Gardner MJ. Mapping cancer mortality in England and Wales. *Br Med Bull* 40 (1984) 320—328.
6. Gardner MJ. Considerations in the choice of expected

- numbers for appropriate comparisons in occupational cohort studies. *Med Lav* 77 (1986) 23—47.
7. Gardner MJ, Winter PD, Barker DJP. Atlas of mortality from selected diseases in England and Wales 1968—1978. Wiley, Chichester 1984.
8. Gardner MJ, Winter PD, Taylor CP, Acheson ED. Atlas of cancer mortality in England and Wales 1968—1978. Wiley, Chichester 1983.
9. Gilson JC. Man-made mineral fibres: What needs to be known and done. *Ann Occup Hyg* 20 (1977) 175—178.
10. Hill ID. Computing man years at risk. *Br J Prev Soc Med* 26 (1972) 132—134.
11. Hill JW. Health aspects of man-made mineral fibres: A review. *Ann Occup Hyg* 20 (1977) 161—173.
12. Office of Population Censuses and Surveys. Mortality statistics, area, England and Wales, 1980—1984. Her Majesty's Stationery Office, London 1982—1985. (Series DH5 no 7—11).
13. Ottery J, Cherrie JW, Dodgson J, Harrison GE. A summary report on environmental conditions at 13 European MMMF plants. In: Guthe T, ed. Biological effects of man-made mineral fibres: Proceedings of a WHO/IARC conference in association with JEMRB and TIMA Copenhagen, 20—22 April 1982. Volume 1. World Health Organization, Regional Office for Europe Copenhagen 1984, pp 83—117.
14. Ottery J, Cherrie J, Harrison GE, Dodgson J. Final report on the environmental survey at Pilkington Brothers Ltd, St Helens. Institute of Occupational Medicine, Edinburgh 1978. (Internal report no BP 31075/2/B(4)2).
15. Ottery J, Cherrie J, Harrison GE, Jones C. Final report on the environmental survey at Turner Brothers Ltd., Hindley Green and Dungannon. Institute of Occupational Medicine, Edinburgh 1980. (Internal report no BP 31075/2/B(4)10).
16. Registrar General. Decennial supplement for England and Wales, 1961, area mortality tables. Her Majesty's Stationery Office, London 1967.
17. Saracci R, Simonato L, Acheson ED, Andersen A, Bertazzi PA, Claude J, Charnay N, Esteve J, Frentzel-Beyme RR, Gardner MJ, Jensen OM, Maasing R, Olsen JH, Teppo L, Westerholm P, Zocchetti C. Mortality and incidence of cancer of workers in the man made vitreous fibres producing industry: An international investigation at 13 European plants. *Br J Ind Med* 41 (1984) 425—436.
18. Simonato L, Fletcher AC, Cherrie J, Andersen A, Bertazzi PA, Charnay N, Claude J, Dodgson J, Estève J, Frentzel-Beyme R, Gardner MJ, Jensen OM, Olsen JH, Saracci R, Teppo L, Winkleman R, Westerholm P, Winter PD, Zocchetti C. The man-made mineral fiber European historical cohort study: Extension of the follow-up. *Scand J Work Environ Health* 12 (1986): suppl 1, 34—47.
19. Stanton MF, Layard M, Tegeris A, Miller E, May M, Morgan E, Smith A. Relation of particle dimension to carcinogenicity in amphibole asbestoses and other fibrous minerals. *J Natl Cancer Inst* 67 (1981) 965—975.
20. Stanton MF, Wrench C. Mechanisms of mesothelioma induction with asbestos and fibrous glass. *J Natl Cancer Inst* 48 (1972) 797—821.
21. World Health Organization. International classification of diseases: Eighth revision. Geneva 1967.