British Journal of Industrial Medicine 1989;46:74–81

Cancer mortality in a cohort of United Kingdom steel foundry workers: 1946–85

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ABSTRACT The mortality experienced by a cohort of 10 491 United Kingdom steel foundry workers during the period 1946–85 has been investigated. These workers were all male operatives first employed in any one of the 10 participating foundries in 1946–65; all had worked in the industry for a minimum period of one year. Compared with the general population of England and Wales, statistically significant excesses relating to cancer mortality were found for cancer of the stomach (E = 77·4, O = 106, SMR = 137) and cancer of the lung (E = 229·2, O = 441, SMR = 147). A statistically significant deficit was found for cancer of the brain (E = 19·4, O = 10, SMR = 51). Involvement of occupational exposures was assessed by the method of regression models and life tables (RMLT). This method was used to compare the duration of employment in the industry, in "dust exposed" jobs, in "fume exposed" jobs, in foundry area jobs, in fettling shop jobs, and in foundry area or fettling shop jobs, of those dying from cancers of the stomach and lung with those of all matching survivors. The RMLT analyses provided evidence of an occupational involvement in the risk of death from lung cancer from work in the foundry area or fettling shop, and weaker evidence of an occupational involvement in the risk of death from stomach cancer from work in the foundry area.

In 1983 a working group of the International Agency for Research on Cancer evaluated the carcinogenic risk of working in iron and steel founding. A report, published the following year, concluded: "The available epidemiological studies provide limited evidence that certain exposures in iron and steel founding are carcinogenic to humans, giving rise to lung cancer. There is inadequate evidence that such exposures result in cancers of the digestive system and genitourinary system. A number of individual compounds for which there is sufficient evidence of carcinogenicity have been measured at high levels in air samples taken from certain areas in iron and steel foundries. Taken together, the available evidence indicates that occupational exposures occur in iron and steel founding which are probably carcinogenic to humans."[1]

The epidemiological studies available for the above evaluation included published reports of mortality among cohorts of foundry workers from North America,[2–10] Scandinavia,[11–12] and the United Kingdom.[13] It is this latter study which is updated here.

Accepted 18 January 1988

Study population

The study population has been described elsewhere,[13] but may be summarised as all male operatives who started work in 10 steel foundries (nine English foundries and one Scottish foundry) between 1946 and 1965, who were employed for at least one year. Office staff and management were excluded. All foundries were members of the Steel Castings Research and Trade Association (SCRATA), which has provided financial and technical help at various times in the history of this study.

Detailed job histories—defined in terms of 25 categories (table 1)—were recorded for each employee.

Follow up procedures have also been described elsewhere.[13] Vital status was supplied by the National Health Service Central Register (NHSCR). For those "no trace" at the NHSCR, vital status was sought from the National Insurance records held by the Department of Health and Social Security (DHSS).

Table 2 shows the vital status of the study population on the closing date of the study, 31 December 1985. For those known to have died, a death certificate

Table 1 *Classification of jobs*

Category	*Range of occupational titles*
	Foundry
Sand preparation*	Sand miller, sand plant service labourer, millman mixer
Moulding*†	Moulder, coremaker, closer, machine moulder, pinlift, shellmoulder, shell coremaker, closer, flame dryer, corestove attendant
Furnace†	Furnaceman, 2nd hand, 3rd hand, spareman, scrapman, ladleman, teemer, caster, ingot man, cupola loader, labourer (steel plant)
Furnace repair*	Furnace fettler, patcher, furnace bricklayer, furnace fitter's mate, furnace serviceman
Centrifugal casting	Spinner, spinning operator, puller out, single end shanker
Foundry cranes†	Cranedriver, mobile crane driver
Labourers, etc	Foundry labourer, fork lift driver, slinger, degreaser's labourer, steel carrier
Knockout*†	Knocker out, knockout labourer, gridman
Other	Alloy storekeeper, descaler, die inspector, chip crusher
	Fettling shop
Fettling*	Fettler, grinder, finisher, dresser, chipper
Blasting*	Shot blaster, hydroblaster, wheelabrator
Burning and welding†	Burner, welder, cutter, powder washer, oxy-cutter, arc air gouger
Heat treatment†	Heat treatment furnaceman, loader, stove attendant (heat treatment), heat treatment labourer
Fettling shop cranes†	Crane driver
Labourers, etc*†	Labourer, service labourer, fork lift driver, press operator assistant, link wrapper, setter's assistant
Other	Blacksmith, dressing shop inspector, setter, stamper, checker, blacksmith striker
	Pattern/machine/maintenance/inspection
Pattern maker	Pattern maker
Pattern shop labourer	Pattern labourer, pattern storeman, labourer, pattern stores, pattern checker
Inspection	Checker, inspector, machinist (inspection), labourer (crack detection), marker off, pressure test, test press assistant
Machining	Turner, machinist, driller, machine shop fitter, miller, borer
Machine shop labourers etc	Labourer, fork lift truck driver, crane driver, machine shop storekeeper, inspector
Welding†	Machine shop welder, maintenance welder
Maintenance	Maintenance fitter, electrician, joiner, blacksmith, pipe fitter
Maintenance mates	Fitter's mate, maintenance craftsman's mate, greaser, belt attendant
Other	Yard labourer, lorry driver, storekeeper, yard bricklayer, despatch labourer, boilerman, tackle shop, assistant blower house attendant

*Jobs attracting higher dust exposure.
†Jobs attracting higher fume exposure.

was obtained with the cause of death coded to the 8th revision of the International Classification of Diseases.

The study population had originally included a further group of 626 workers with Indian, Pakistani, or Arab surnames. Overall mortality was found to be suspiciously low for this group (Exp = 87·6, Obs = 35, SMR = 40) and these workers have, therefore, been excluded from all analyses detailed in this report.

Table 2 *Vital status at closing date of study (31 December 1985)*

	No	*%*
"Flagged" alive at the NHSCR	6833	65·2
Traced alive at the NI offices	192	1·8
Emigrated	204	1·9
No trace	129	1·2
Died, cause known	3110	29·7
Died, cause not known	23	0·2
Total	10491	100·0

Methods

The mortality experience of this cohort was compared with that which might have been expected to occur if rates of death for the general population of England and Wales had been operating on the study cohort, having due regard to the composition of the study cohort by age, sex, and calendar year.

Expectations based on person-years at risk (pyr) were calculated using the Manyears computer program developed by J Peto. Individuals entered the pyr at the end of the first year of employment and left on the date of death, date of embarkation, "date last known alive," or the closing date of the study, whichever was the earlier. Individuals were "censored" on reaching their 85th birthday—that is, they make no further contributions to expected or observed numbers past this age. This was done for two reasons: firstly, national death rates are only available for the "open ended" age group "$\geqslant 85$," the composition of which in the general population by individual years of age may differ greatly from that of the study population and, secondly, any individual incorrectly traced, for whatever reason, as still living would make a particularly large contribution to expectations for this age group.

This placed the mortality experience of the study cohort in broad perspective. The differences found, however, between the mortality of an industrial cohort and an expected experience based on rates of mortality for the general population also depend on factors other than the specific occupational exposure. Such factors will include selection effects within the workforce as well as the regional, urban/rural, and social class composition of the study cohort. The method of regression models in life tables (RMLT) was used, therefore, to test the null hypothesis of no effect on mortality from duration of "exposed" employment in the industry, contrasting groups from within the study population.[14-18] This approach was used because, by relying on internal comparisons, we believe that we

Table 3 *Steel foundry workers: cancer mortality, 1946–85*

Site	*ICD 8th*	*Obs*	*Exp*	*SMR*
Lip	140	0	0·3	0
Tongue	141	4	2·4	170
Mouth	143–5	2	2·2	90
Pharynx	146–9	3	5·1	59
Oesophagus	150	15	21·2	71
Stomach	151	106**	77·4	137†
Small intestine	152	1	1·5	65
Large intestine	153	40	43·4	92
Rectum	154	40	33·3	120
Liver	155	2	4·9	41
Gallbladder	156	3	4·2	71
Pancreas	157	34	31·2	109
Nose, sinuses	160	4	1·6	251
Larynx	161	8	6·9	116
Lung	162, 3	441***	299·2	147†
Bone	170	1	2·6	39
Skin	172, 3	3	6·5	46
Breast	174	0	0·9	0
Prostate	185	22	31·5	70
Testis	186	3	3·1	97
Bladder	188	25	26·2	96
Other genital	187	0	1·1	0
Other urinary	189	14	13·4	105
Brain	191, 2	10(*)	19·4	51
Thyroid	193	2	1·3	149
Lympho	200, 202	12	14·1	85
Hodgkins	201	5	7·0	72
Myeloma	203	9	7·4	122
Leukaemia	204–207	14	17·6	79
All cancers	140–209	862***	726·8	119

Two tailed tests: *$p < 0·05$; **$p < 0·01$; ***$p < 0·001$.
( ) indicates significant deficit.
†The use of Scottish rates of mortality for the Scottish foundry provided overall SMRs of 136 and 146 for cancer of the stomach and cancer of the lung respectively.

may control for selection effects, and regional, urban/rural, and social class effects.

The method[15–18] was used to compare the duration of exposed employment of those who died from the cause under investigation with those of all matching survivors, while controlling for year of starting employment (1946–50, 1951–5, 1956–60, 1961–5), age at starting employment (15–, 20–, 25–, 30–, 35–, 45–, ≥55), factory (10 participating factories), and year of follow up. In some instances it was also possible to include "duration of employment in the industry" as a controlling factor, to try and control for any "survivor population effect" in the data.

Expert advice was sought on the most appropriate classification of job titles into (*a*) those jobs attracting higher dust exposures and (*b*) those jobs attracting higher fume exposures. Our overall classification is shown in table 1. Four of the participating foundries suggested that slight modifications in the classification would be appropriate for their particular foundry, and these modifications were accepted. Individual factories will differ in terms of chemicals found in the workplace, factory operating procedures, and lay out of the factory. There will also be changes over time. The classification, then, is a broad classification.

The data were first divided into a large number of subgroups by levels of the controlling variables mentioned above. For each subgroup (or subcohort) a life table was constructed, giving for each year of follow up the number entering that year of follow up, the number dying from the cause under investigation, and the mean duration of exposed employment of these two categories.

Extent of occupational exposure was estimated in five ways:

(1) cumulative duration of employment in the industry (irrespective of which departments were worked in);

(2) cumulative duration of employment in jobs attracting higher levels of dust exposure (see table 1);

(3) cumulative duration of employment in jobs attracting higher levels of fume exposure (see table 1);

(4) cumulative duration of employment in foundry area jobs;

(5) cumulative duration of employment in fettling shop jobs; and

Table 4 *Mortality from stomach cancer by first occupational category*

Occupation	*Obs*	*Exp*	*SMR*
	Foundry		
Sand preparation	2	1·3	156
Moulding	10	6·3	159
Furnace	11**	4·2	265
Furnace repair	13***	3·6	359
Centrifugal casting	1	1·0	102
Foundry cranes	2	2·1	95
Labourers, etc	13	12·9	101
Knockout	2	1·1	185
Other	3	0·8	364
All foundry occupations	57***	33·3	171
	Fettling shop		
Fettling	5	6·6	76
Blasting	1	1·0	104
Burning & welding	1	2·0	50
Heat treatment	1	0·6	154
Fettling shop cranes	1	0·9	108
Labourers, etc	6	3·9	155
Other	1	0·8	128
All fettling shop occupations	16	15·8	101
	Pattern/machine/maintenance/inspection		
Pattern making	1	1·0	97
Pattern shop labourer	3	0·8	354
Inspection	3	2·1	141
Machining	8	6·3	127
Machine shop labourers, etc	7	6·0	116
Welding	0	0·4	0
Maintenance	5	4·5	112
Maintenance mates	4	3·2	126
Other	2	4·0	50
All pattern/machine/maintenance	33	28·3	117

*$p < 0·05$; **$p < 0·01$; ***$p < 0·001$.

Table 5 *Mortality from lung cancer by first occupational category*

Occupation	*Obs*	*Exp*	*SMR*
	Foundry		
Sand preparation	4	5·1	79
Moulding	33	25·2	131
Furnace	29**	16·4	177
Furnace repair	24*	14·1	171
Centrifugal casting	9*	3·7	244
Foundry cranes	12	8·4	142
Labourers, etc	80***	48·3	166
Knockout	4	4·2	95
Other	5	2·8	177
All foundry occupations	200***	128·2	157
	Fettling shop		
Fettling	49***	26·4	186
Blasting	4	3·8	105
Burning & welding	13	8·3	157
Heat treatment	5	2·5	197
Fettling shop cranes	4	3·7	109
Labourers, etc	25*	14·7	171
Other	5	3·0	165
All fettling shop occupations	105***	62·4	168
	Pattern/machine/maintenance/inspection		
Pattern making	7	4·1	171
Pattern shop labourer	2	3·2	63
Inspection	6	8·1	74
Machining	37*	25·4	146
Machine shop labourers, etc	29	21·0	138
Welding	3	1·5	197
Maintenance	18	17·4	104
Maintenance mates	23**	12·3	187
Other	11	15·4	71
All pattern/machine/ maintenance	136**	108·4	125

*$p < 0·05$; **$p < 0·01$; ***$p < 0·001$.

(6) cumulative duration of employment in foundry area or fettling shop jobs.

The null hypothesis of no effect on mortality from duration of exposed employment is that the deaths in each year are a random sample from the entrants to that year, and that the differences in the mean cumulative duration of exposed employment of these two categories should be zero.

A test statistic was calculated to determine the probability of observing by chance alone the differences found between the duration of exposed employment of those who have died and the duration of exposed employment of the matching survivors—that is, if the null hypothesis of no effect on mortality from duration of exposed employment is true. Thus with a test statistic greater than $\pm 1·96$, the null hypothesis is rejected at the 5% level.

A positive test statistic indicates that deaths from the cause under investigation tend to occur among those with longer periods of exposed employment, which could be due to the existence of an occupational risk factor, or bias, or confounding, or chance. A negative test statistic indicates that deaths from the cause under investigation are tending to occur among those with shorter periods of exposed employment, which could be due to the existence of protective occupational exposures, or bias, or confounding, or chance.

Results

SMR APPROACH

The existence of any healthy worker effect in the data is best investigated by calculating SMRs for successive periods from first employment (irrespective of how long any individual remains in the industry).[19] For successive 10 year periods from first employment, SMRs for all cancers were 105, 136, 109 and 119 respectively, and SMRs for all non-cancers were 95, 117, 111, and 111 respectively. Although SMRs for these two broad cause of death groupings are lowest in the 10 year period following first employment, a general trend of increase is not shown over the follow up period. There is, then, only limited evidence of a healthy worker effect in these data.

Table 3 shows overall results for cancer mortality by site. Compared with the general population, there are statistically significant excesses for cancer of the stomach, cancer of the lung, and all cancers and a statistically significant deficit for cancer of the brain.

Table 4 shows observed and expected numbers of deaths by first occupation for cancer of the stomach. The excess is found predominantly in foundry occupations (all foundry occupations, SMR = 171) and, in particular, "furnace" and "furnace repair."

Table 5 shows observed and expected numbers of deaths by first occupation for cancer of the lung. SMRs are higher for all foundry occupations (SMR = 157) and all fettling shop occupations (SMR = 168) than for pattern/machine/ maintenance/inspection (SMR = 125), although statistically significant excesses are shown for several occupations within each of these three broad categories (foundry: furnace, furnace repair, centrifugal casting, labourers etc; fettling shop: fettling, labourers etc; pattern/machine/maintenance/ inspection: machining, maintenance mates).

Table 6 shows observed and expected numbers of deaths for stomach cancer and lung cancer by entry cohort and by successive 10 year periods from first employment. For stomach cancer, SMRs tend to be higher 10–19 years from first employment, with little evidence of excess mortality 20 years or more from first employment. For lung cancer, there is evidence, among three of the four cohorts, of a trend of SMRs increasing with period from first employment.

Table 7 shows observed and expected numbers of

Table 6 *Steel foundry workers: mortality from stomach cancer and lung cancer 1946–85 by entry cohort and by years from first employment*

	Entry cohort									
*Years from first employment**	*1946–50 SMR*	*(O)*	*1951–5 SMR*	*(O)*	*1956–60 SMR*	*(O)*	*1961–5 SMR*	*(O)*	*Total SMR*	*(O)*
Cancer of stomach:										
0–9	224	(8)	86	(4)	164	(5)	82	(2)	139	(19)
10–19	150	(10)	214	(18)	214	(12)	162	(7)	188	(47)
20–29	119	(11)	118	(13)	54	(3)	80	(1)	103	(28)
⩾30	110	(9)	90	(3)	—	—	—	—	104	(12)
Total	137	(38)	139	(38)	140	(20)	125	(10)	137	(106)
Cancer of lung:										
0–9	106	(9)	119	(16)	163	(17)	120	(11)	127	(53)
10–19	126	(27)	155	(47)	199	(44)	146	(27)	157	(145)
20–29	124	(45)	154	(72)	145	(36)	233	(13)	146	(166)
⩾30	142	(52)	169	(25)	—	—	—	—	149	(77)
Total	129	(133)	152	(160)	169	(97)	154	(51)	147	(441)

*Irrespective of how long any individual remains in the industry.

deaths for stomach cancer and lung cancer by first work area and by successive 10 year periods from first employment. For stomach cancer, the highest SMR is shown for all foundry occupations 10–19 years from first employment. SMRs for all fettling shop occupations decrease with time from first employment. For lung cancer, similar SMRs are shown for the foundry area but for the fettling shop there is a tendency for SMRs to increase with period from first employment.

RMLT APPROACH

The method of regression models and life tables (RMLT) was used to investigate any association between the risk of death from lung cancer and stomach cancer and duration of employment in the industry or duration of employment in various job categories.

Table 8 shows overall test statistics, derived from comparing the duration of employment (variously defined) of those dying from lung cancer, stomach cancer, or all causes with those of all matching survivors. No statistically significant positive test statistics were found, although the test statistic shown for cancer of the stomach and duration of employment in the foundry area approached significance ($t = +1{\cdot}74$, $p = 0{\cdot}08$), as did that for cancer of the lung and duration of employment in the foundry area or fettling shop ($t = +1{\cdot}66$, $p = 0{\cdot}10$). For each of the six test factors shown, the mean difference in duration of exposed employment between deaths and matching survivors was larger (in the positive direction) for lung cancer than it was for all causes.

A further test statistic was calculated for cancer of the stomach and duration of employment in the

Table 7 *Steel foundry workers: mortality from stomach cancer and lung cancer 1946–85 by first work area and by years from first employment*

	First work area							
*Years from first employment**	*All foundry occupations SMR*	*(O)*	*All fettling occupations SMR*	*(O)*	*Pattern/machine/maintenance SMR*	*(O)*	*Total SMR*	*(O)*
Cancer of stomach:								
0–9	137	(8)	168	(4)	128	(7)	139	(19)
10–19	255	(27)	162	(8)	127	(12)	188	(47)
20–29	155	(18)	50	(3)	73	(7)	103	(28)
⩾30	77	(4)	40	(1)	182	(7)	104	(12)
Total	171	(57)	102	(16)	116	(33)	137	(106)
Cancer of lung:								
0–9	153	(27)	70	(5)	125	(21)	127	(53)
10–19	165	(64)	195	(36)	128	(45)	157	(145)
20–29	153	(74)	157	(40)	131	(52)	146	(166)
⩾30	151	(35)	213	(24)	105	(18)	149	(77)
Total	156	(200)	168	(105)	125	(136)	147	(441)

*Irrespective of how long any individual remains in the industry.

Table 8 *Testing the null hypothesis of no effect from duration of employment in various job groupings on risk of death from stomach cancer, lung cancer, and all causes, by the method of RMLT*†

Cause of death (No of deaths) and test factor‡	*Mean duration of exposed employment of deaths*§	*Mean difference between deaths and matching survivors*§	*Test statistic*‖
Cancer of stomach (n = 106):			
Industry	7·1	−0·9	−1·42
Dust exposed jobs	1·9	−0·2	−0·54
Fume exposed jobs	1·8	−0·1	−0·28
Foundry area	3·4	+0·7	+1·74
Fettling shop	1·0	−0·5	−1·42
Foundry area and/or fettling shop	4·4	+0·2	+0·51
Cancer of lung (n = 441):			
Industry	8·8	−0·2	−0·46
Dust exposed jobs	3·2	+0·3	+1·27
Fume exposed jobs	2·8	+0·1	+0·35
Foundry area	3·7	+0·2	+0·88
Fettling shop	2·4	+0·2	+0·95
Foundry area and/or fettling shop	6·1	+0·4	+1·66
All causes (n = 3102):			
Industry	8·5	−0·3	−2·77(**)
Dust exposed jobs	2·8	+0·1	+0·67
Fume exposed jobs	2·3	−0·2	−2·49(*)
Foundry area	3·3	−0·1	−0·69
Fettling shop	2·0	0·0	+0·43
Foundry area and/or fettling shop	5·3	0·0	−0·29

*p <0·05; **p < 0·01. () = Significant negative statistic.
†Controlling for age at hire (15–, 20–, 25–, 30–, 35–, 45–, ⩾55), year of hire (1946–50, 1951–5, 1956–60, 1961–5), foundry (10 participating foundries). For test factors 2–6 inclusive, also controlling for duration of employment in the industry (1–2, 3–7, ⩾8 years).
‡See table 1.
§In units of years of employment in jobs defined by the various test factors.
‖Asymptotically normally distributed.

foundry area, with periods of exposed employment "lagged" by ten years. Table 9 shows contributions from subcohorts to the overall test statistics both for lagged and unlagged periods of exposed employment. The overall test statistic for lagged exposures was reduced to +1·62, although the test statistic for the period 10–19 years from first employment was increased from +1·83 to +2·37 (p = 0·06 to p = 0·02). Statistically significant test statistics are also shown for the most recent entry cohort (first employed 1961–5) and for short term workers. These are not mutually exclusive categories.

The results of a similar analysis are shown in table 10 for lung cancer and duration of employment in the foundry area or fettling shop. The overall test statistic for lagged exposures was increased to +2·33 (p < 0·05). Statistically significant test statistics are also shown for the earlier entry cohort (first employed 1946–50) and for long term workers. These are not mutually exclusive categories.

Test statistics for the first three test factors were also calculated for cancer of the oesophagus, cancer of the bladder, all reticuloendothelial systems neoplasms, all cancers, diseases of the circulatory system, and diseases of the respiratory system (non-malignant). No statistically significant positive statistics were obtained.

Discussion

A general discussion of the methodology used in this analysis may be found elsewhere.[17] Cancers of the stomach and of the lung were chosen for more detailed

Table 9 *Testing the null hypothesis of no effect from duration of employment in foundry area jobs on risk of death from stomach cancer, by the method of RMLT*†. *Results shown by controlling variables for unlagged and lagged periods of exposed employment*

Controlling variables	*No of deaths*	*Mean duration of exposed employment of deaths*§	*Mean difference between deaths and matching survivors*§	*Test statistic*‖
With unlagged periods of exposed employment				
By entry cohort				
1946–50	38	3·3	+0·3	+0·40
1951–55	38	3·9	+1·2	+1·72
1956–60	20	1·8	−0·4	−0·48
1961–65	10	5·5	+2·8	+2·30*
By duration of employment in the industry (y)				
1–2	39	1·2	+0·3	+2·14*
3–7	33	2·5	+0·7	+1·62
⩾8	34	6·9	+1·3	+1·02
By period from first employment (y)				
0–9	19	1·5	+0·3	+0·74
10–19	47	3·7	+1·1	+1·83
⩾20	40	4·0	+0·6	+0·65
Total	106	3·4	+0·7	+1·74
With periods of exposed employment lagged by 10 years				
By entry cohort				
1946–50	38	2·4	+0·3	+0·52
1951–55	38	2·5	+0·7	+1·39
1956–60	20	1·3	+0·1	+0·15
1961–65	10	2·1	+1·1	+2·38*
By duration of employment in the industry (y)				
1–2	39	0·9	+0·3	+2·18*
3–7	33	1·5	+0·5	+1·52
⩾8	34	4·2	+0·7	+0·86
By period from first employment (y)				
0–9	19	n/a	n/a	n/a
10–19	47	1·9	+0·6	+2·37*
⩾20	40	3·6	+0·5	+0·72
Total	106	2·2	+0·5	+1·62

*p <0·05.†; ‖: see table 8.
§In units of years of employment in foundry area jobs (see table 1).

Table 10 *Testing the null hypothesis of no effect from duration of employment in foundry area or fettling shop jobs on risk of death from lung cancer by the method of RMLT†. Results shown by controlling variables for unlagged and lagged periods of exposed employment*

Controlling variables	*No of deaths*	*Mean duration of exposed employment of deaths§*	*Mean difference between deaths and matching survivors§*	*Test statistic‖*
With unlagged periods of exposed employment				
By entry cohort				
1946–50	133	8·3	+1·2	+2·14*
1951–55	160	5·3	0·0	+0·03
1956–60	97	4·9	+0·2	+0·41
1961–65	51	4·5	+0·1	+0·18
By duration of employment in the industry (y)				
1–2	109	1·1	0·0	−0·51
3–7	143	3·4	+0·3	+1·56
≥8	189	10·9	+0·8	+1·37
By period from first employment (y)				
0–9	53	2·4	+0·1	+0·21
10–19	145	5·7	+0·6	+1·48
≥20	243	7·0	+0·4	+1·06
Total	441	6·1	+0·4	+1·66
With periods of exposed employment lagged by 10 years				
By entry cohort				
1946–50	133	6·7	+1·1	+2·45*
1951–55	160	4·0	+0·3	+1·26
1956–60	97	2·8	0·0	+0·09
1961–65	51	2·0	−0·3	−0·85
By duration of employment in the industry (y)				
1–2	109	0·9	0·0	+0·26
3–7	143	2·6	+0·2	+1·28
≥8	189	7·6	+0·8	+2·04*
By period from first employment (y)				
0–9	53	n/a	n/a	n/a
10–19	145	3·0	+0·3	+1·43
≥20	243	6·1	+0·6	+1·96
Total	441	4·3	+0·4	+2·33*

*$p < 0·05$.†; ‖: see table 8.
§In units of years of employment in foundry area or fettling shop jobs (see table 1).

analysis on the basis of both the high overall SMRs obtained in this study and the published findings from other studies.[1] The test factors considered in the RMLT analysis were known to be relatively crude, although believed to merit consideration.

Some suggestive evidence of an occupational involvement in death from cancer of the stomach from working in the foundry area was provided both by the SMR and the RMLT analyses. This hypothesis was not supported, however, by the unexceptional SMRs shown for the period 20 years or more from first employment, nor by finding the more significant RMLT test statistics among short term (rather than long term) workers.

The RMLT analysis of employment in the foundry area or fettling shop, provided more convincing evidence of an occupational involvement in mortality for cancer of the lung. Attempts at uncovering a more specific work association were unsuccessful.

Data on smoking histories were unfortunately not available, although there is no good reason to believe that they would correlate with any of the test factors considered. Data on employment history outside of the 10 study foundries were also unavailable. This may be a serious limitation, particularly if our short term foundry workers moved on to foundry work elsewhere.

In conclusion, the RMLT analyses provided evidence of an occupational involvement in lung cancer mortality from working in the foundry area or fettling shop, and weaker evidence of an occupational involvement in stomach cancer mortality from working in the foundry area.

Although there are obvious practical problems in gaining a detailed historical assessment of work processes, practices, and conditions at each of the 10 participating foundries, such an assessment could usefully be incorporated into this study for further analysis.

We thank the Colt Foundation for its generous financial support of this analysis, SCRATA and the HSE for their previous financial support and current technical help, Antony Fletcher for his important work in this field of research, and Ann Balnaves for word processing and editing and checking the data. We also thank Sir Richard Doll for helpful comments on an earlier draft.

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