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Epidemiological survey of oil distribution centres in Britain

L RUSHTON AND M R ALDERSON

From the Division of Epidemiology, Institute of Cancer Research, Sutton, Surrey SM2 5PX, UK

ABSTRACT A mortality study of workers employed for at least one year between 1 January 1950 and 31 December 1975 at oil distribution centres from three oil companies in Britain has been carried out. Ninety nine per cent of the population were successfully traced to determine their vital status at 31 December 1975. The mortality observed in the study population was compared with that which would be expected from the mortality rates for all the male population of England and Wales. The overall mortality observed was considerably lower than expected on this basis as was the mortality from stroke, hypertensive disease, bronchitis, and pneumonia. The observed number of deaths from all neoplasms was also much less than expected as were the observed deaths from lung cancer. The observed deaths from ischaemic heart disease approximately equalled those expected overall and in each of the companies, however, and there was no evidence of a "healthy worker effect" for this disease group. The ratio of observed over expected deaths from ischaemic heart disease tended to decrease with increasing age at death, and for most of the job groups overall, the observed and expected deaths were about the same. Raised mortality patterns from ischaemic heart disease were found in several subgroups of the population of one company. Mortality from myelofibrosis and diseases of the lymphatic and haematopoietic tissue was slightly raised overall. Only myelofibrosis showed an overall excess but raised mortality was found in subgroups of the population defined by company, job, and length of service in several of the other neoplasms making up this disease group. The numbers of deaths from these causes were all small, making it difficult to exclude chance effects. Further work would be required to ascertain whether these results are due to an occupational factor and if so to identify the physical or chemical nature of the risk.

The present study is the third part of a wider study of workers in the oil industry which has been carried out by the same research team. A similar mortality study of workers in oil refineries[1] and a case control study to investigate the possible association between exposure to benzene and death from leukaemia in refinery workers have been carried out.[2] Many aspects of the design, method, and analyses of the distribution centre study are similar to those used in the oil refinery study.[1] A study of maintenance men at London Transport bus garages and Chiswick Works has also been carried out.[3]

Previous studies on the hazards associated with oil

Many papers have described the carcinogenic effects of exposure to mineral oil, both to animals[4,5] and people in various occupations.[6,7] In the petroleum industry specific issues investigated include the health of asphalt workers,[8] the occurrence of skin cancer, and cancer of the scrotum in wax pressmen.[9,10] Several mortality studies have also been carried out on oil refinery workers.[1,11–13] There have been relatively few studies of workers in oil distribution centres although they have been included in wider studies of the oil industry or studies of populations defined by their proximity to the petroleum industry.[14–16] Several studies have measured (*a*) the intake of benzene vapour, a constituent of petrol, using personal air sampling and (*b*) the metabolism of benzene evaluated from the concentration of phenol in urine for workers at bulk marketing terminals and for petrol pump attendants at garages.[17–20] A study of marine terminals describes the source of hydrocarbon emissions and discusses the problem of safety involved in the application of control technology.[21]

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Measurement of hydrocarbon vapour concentrations in the employees' breathing zone using various loading and control systems for gasoline tank trucks was carried out.[22] It was concluded that gasoline exposure to driver salesmen and to loaders at loading racks did not pose a health hazard. The importance of controlling any leaks, spills, and improper loading procedures that might contribute to employees' exposure was emphasised.

A survey of the nature and duration of mineral oil exposure at selected oil distribution terminals in one United Kingdom company was carried out (E King, unpublished data, 1969). The cleanliness of the plants and the men operating them and the potential areas of oil exposure were described for the various processes in each terminal. The washing facilities, provision of protective clothing, and display of warning notices at each terminal were also discussed.

Method

The present study included all men with a length of service of at least one continuous year between 1 January 1950 and 31 December 1975 at distribution centres in Britain. The distribution centres include airports and blending plants. Three companies (A, B, and C) provided the data.

The following data were collected from personnel and pension departments at the company head and regional offices: for all men full name, date of birth, address, distribution centre, date of joining, and last or present job; for leavers, date of leaving, reason for leaving (retired, died, or other), and National Insurance (NI) number if available.

A feasibility study had considered collecting a detailed job history for each man but this would have been a lengthy and costly task. The availability of job history information was also inconsistent between companies. It was therefore decided to use last job title. As many different job titles were used by the companies these were coded to 11 broader job groups (table 1). For the analyses the following groups have been combined to provide large enough numbers: operators and greasemakers; craftsmen, motor mechanics, scientists, and technicians; and administrators, clerical workers, and managers. These are referred to as operators, craftsmen, and administrators respectively.

Table 1 *Distribution of job classification of study population (not including untraced men)*

	No	*(%)*
Operators	4660	(20)
Greasemakers	44	(0)
Drivers	10108	(43)
Craftsmen	796	(4)
Motor mechanics	582	(3)
Scientists/technicians	217	(1)
General manual workers	1612	(7)
Security men	467	(2)
Supervisors	1686	(7)
Administrators/clerical workers	2369	(10)
Managers	765	(3)
Total	23306	(100)

Information, including dates of death, was available on pensioners from some companies. All other leavers, where contact with the company had been lost, were traced either through the Social Security records at Newcastle or through the National Health Service Central Registers (NHSCR) at Southport and Edinburgh. Full details of death were obtained for all men found to be dead either directly from the NHSCRS or from the Office of Population Censuses and Surveys.

As there were no National Health Service numbers available from the companies and some records did include the National Insurance number all tracing was done through the Social Security records first and the NHSCRs were then used if this first attempt was unsuccessful.

The causes of death, both underlying cause and up to three contributory causes, were coded using the appropriate revision of the International Classification of Diseases.[23] In the analysis the underlying cause was used in comparing observed with expected deaths. The contributory causes were used to identify other cases where the disease of interest was an associated cause rather than the actual cause of death.

The number of years each man was in the study (person years) was calculated from his date of birth and dates of entry to and exit from the study using the man years computer language program.[24] The total person years were subdivided into five year age and calendar period groups. As all men in the study had a minimum of one year's service between 1 January 1950 and 31 December 1975 date of entry to the study was (*a*) 1 January 1951 for men who joined before 1950 and (*b*) one year after joining for those who joined after 1 January 1950.

The expected deaths were calculated by applying the five year age and calendar period death rates of the comparison population to the five year age and calendar period person years of the study population to obtain age and calendar period expected deaths which were summed to give the total expected deaths.

The comparison population used in the distribution centre study was the population of men in England and Wales. In the refinery study[1] the expected deaths for the two Scottish refineries were calculated using Scottish rates. A correction was also made for geographical variation in mortality for the England and Welsh refineries using a simple method based

on the three standard regions in which the refineries were sited. It was decided not to do this for the distribution centre study as separating the data into Scotland and ten standard regions in England and Wales would have reduced the numbers too much for analysis. Nevertheless, the geographical position of particular centres has been taken into account in the interpretation of the results.

In addition to differences in mortality between areas some diseases show well defined gradients of mortality across the social classes. The interpretation of the results from adjustment of expected deaths for social class variation and the limited mortality data available by social class for a detailed list of cause of death has been discussed.[1] In the present study social class adjustment has not been carried out. When interpreting the results for the various job groups used in this study, due consideration has been given to known social class variation and an attempt made to judge whether the difference between observed and expected deaths is likely to reflect non-occupational factors.

The grouping of the causes of death was determined by that of the available comparison data. For 30 malignant causes the groups were those used in the serial mortality tables.[25] For the non-malignant causes, data for the A list of 150 causes of death from the 7th revision of the International Classification of Diseases were made available by the World Health Organisation.

The difference between the observed and expected deaths was examined by calculating a significance level (p value) for the observed number of deaths assuming it to be drawn from a Poisson distribution with mean equal to the externally calculated expected value.

As in the previous refinery study[1] two approaches to the analysis were used. Firstly, a search for pronounced excesses and deficits in numbers of observed deaths compared with those expected was made. An examination of the data by company, age, job, year of entry, length of service, and reason for leaving was then carried out to describe and estimate the patterns of mortality more fully. Since, in this approach, hypotheses were not being formally tested, the significance levels obtained in these analyses have been used informally as guidelines to indicate the magnitude and direction of the variations in mortality. The second approach involved a priori testing of the findings from previous studies discussed in the introduction.

Results

Table 2 gives the status of the study population at the study end date, 31 December 1975. Only 0·2% of the men were untraced and these have not been included in the analysis. There was a total of 397 569 person years of observation with a mean follow up of 17·1 years for each man.

Table 2 *Status of study population at study end date 31 December 1975*

	No	*(%)*
In employment	8470	(36·3)
Left employment		
Alive	10904	(46·7)
Dead, cause known	3903	(16·7)
Dead, cause unknown	23	(0·1)
Emigrated	6	(0·0)
Untraced	52	(0·2)
Total	23358	(100·0)

NON-MALIGNANT CAUSES OF DEATH

The total number of non-malignant deaths was significantly lower than expected (table 3), a deficit that is also reflected in some of the circulatory disease groups including chronic rheumatic heart disease, other diseases of the heart, and hypertensive disease. The same is true for diseases of the respiratory system, especially tuberculosis, influenza, pneumonia, and bronchitis.

In general the pattern of lowered mortality from these disease groups was found across all subgroups (defined, for example, by job, age, and length of service). There were three excesses overall for general manual workers: cerebrovascular disease (O = 52, E = 36·98, $p < 0·01$); other diseases of the circulatory system (O = 6, E = 2·90, p = 0·07); and asthma (O = 4, E = 0·76, $p < 0·01$). There was also an excess from bronchitis for security men (O = 37, E = 25·56, $p < 0·05$).

There were slightly more deaths overall from motor vehicle accidents, especially in company B (O = 57/45·50, p = 0·06). Just under half the deaths in this company were men who left for "other reasons" (O = 27, E = 13·29, $p < 0·01$), often after less than five years' service. Many of the motor vehicle accidents were in fact motor cycle accidents.

There were seven deaths from accidental fire and explosion (O = 7, E = 4·2, p = 0·13) but only five of these were due to accidents at work.

Ischaemic heart disease

There were approximately the same number of deaths observed (1377) from ischaemic heart disease as expected (1384). In most occupational mortality studies of this type, where the national population is used for comparison, a significant deficit would be expected from this disease. More detailed results for this disease group are thus now presented.

Table 4 gives the observed (O) and expected (E) deaths, O/E, and p values by age, job, year of entry,

Table 3 *Observed and expected deaths (O/E) and p values for all causes and non-malignant causes with 10 or more observed deaths for workers employed in oil distribution centres in Britain from 1 January 1950 to 31 December 1975*

Causes (in ICD order)	*Observed deaths*	*Expected deaths*	*O/E*	*p*
All causes	3926	4632·13	0·85	< 0·0001
Tuberculosis of respiratory system	11	49·19	0·22	< 0·0001
Diabetes	19	26·49	0·72	0·08
Cerebrovascular disease	374	430·70	0·87	0·01
Chronic rheumatic heart disease	31	59·37	0·52	< 0·0001
Ischaemic heart disease	1377	1384·24	0·99	0·84
Other diseases of heart	71	110·70	0·64	< 0·001
Hypertensive disease	65	91·93	0·71	< 0·01
Diseases of arteries	81	88·86	0·91	0·22
Other diseases circulatory system	36	35·94	1·00	0·52
Influenza	13	26·12	0·50	< 0·01
Pneumonia	133	185·28	0·72	< 0·0001
Bronchitis	240	358·63	0·67	< 0·0001
Asthma	15	15·18	0·99	0·55
Peptic ulcer	40	50·73	0·79	0·07
Chronic and other nephritis	15	32·27	0·46	< 0·001
Infections of the kidney	11	12·63	0·87	0·39
Hyperplasia of prostate	10	16·38	0·61	0·07
Other diseases genitourinary system	10	7·70	1·30	0·25
Motor vehicle accidents	75	69·92	1·07	0·29
Accidental falls	17	24·36	0·70	0·08
Suicide	38	67·06	0·57	< 0·0001

Table 4 *Observed deaths (O), expected deaths (E), O/E, and p values for ischaemic heart disease by company, age, job, year of entry, and length of service**

	Company A				*Company B*				*Company C*				*Total*			
	O	*E*	*O/E*	*p*	*O*	*E*	*O/E*	*p*	*O*	*E*	*O/E*	*p*	*O*	*E*	*O/E*	*p*
Total population	78	83·19	0·94	0·31	834	832·19	1·00	0·95	465	468·86	0·99	0·84	1377	1384·24	0·99	0·84
Age:																
<45	5	5·97	0·84	0·45	58	48·00	1·21	0·09	14	15·20	0·92	0·45	77	69·17	1·11	0·19
45–54	24	18·25	1·32	0·11	188	154·30	1·22	0·007	64	61·43	1·04	0·39	276	233·98	1·18	0·00
55–64	23	27·93	0·82	0·20	259	269·41	0·96	0·50	148	152·99	0·97	0·67	430	450·33	0·95	0·33
65–74	17	23·40	0·73	0·11	265	269·71	0·98	0·77	189	182·14	1·04	0·60	471	475·25	0·99	0·84
≥75	9	7·63	1·18	0·36	64	90·76	0·71	0·002	50	57·09	0·88	0·19	123	155·48	0·79	0·00
Job:																
Operator	6	8·52	0·70	0·25	170	162·01	1·05	0·53	115	107·23	1·07	0·45	291	277·76	1·05	0·42
Driver	34	30·56	1·11	0·29	305	307·56	0·99	0·59	154	157·54	0·98	0·37	493	495·66	0·99	0·66
Craftsman	10	5·17	1·93	0·04	40	44·35	0·90	0·29	38	43·67	0·87	0·22	88	93·19	0·94	0·32
General manual worker	8	14·95	0·54	0·04	70	64·86	1·08	0·28	40	30·58	1·31	0·06	118	110·39	1·07	0·46
Security man	7	8·33	0·84	0·41	49	58·93	0·83	0·11	9	15·52	0·58	0·05	65	82·78	0·79	0·03
Administrator	7	9·68	0·72	0·25	121	106·20	1·14	0·15	56	53·25	1·05	0·37	184	169·22	1·09	0·26
Supervisor	6	5·98	1·00	0·55	79	88·19	0·90	0·18	53	61·07	0·87	0·17	138	155·24	0·89	0·16
Year of entry:																
Pre-1940	12	13·56	0·88	0·40	446	445·43	0·98	0·20	384	380·77	1·01	0·86	842	849·76	0·99	0·78
1940–9	20	21·20	0·94	0·45	186	194·50	0·96	0·53	34	37·24	0·91	0·33	240	252·94	0·95	0·41
1950–9	42	39·28	1·07	0·35	147	142·40	1·03	0·67	32	35·55	0·90	0·31	221	217·23	1·02	0·79
≥1960	4	9·15	0·44	0·05	55	39·86	1·38	0·01	15	15·31	0·98	0·54	73	64·32	1·15	0·13
Length of service (years):																
0– 4	23	24·40	0·94	0·44	75	73·15	1·03	0·43	4	7·45	0·54	0·14	102	105·00	0·97	0·93
5– 9	15	18·18	0·83	0·27	89	103·00	0·86	0·17	15	13·78	1·09	0·41	119	134·96	0·88	0·17
10–14	14	15·32	0·91	0·43	105	94·16	1·12	0·14	19	22·55	0·84	0·27	138	132·03	1·05	0·59
15–19	14	8·92	1·57	0·07	114	93·09	1·22	0·02	30	37·28	0·80	0·13	158	139·29	1·13	0·11
≥20	12	16·36	0·73	0·17	451	468·77	0·96	0·41	397	387·82	1·02	0·65	860	872·95	0·99	0·66

*Results for the 1377 deaths are repeated for each of the classifying variables of age, job, year of entry, and length of service.

and length of service for each company and the total population. The ratio of observed over expected deaths tended to decrease with increasing age at death. A slight excess was found in company B for deaths aged under 45 and pronounced excesses for men aged 45–54 at death for company B and overall. There was a pronounced deficit for men aged 75 or over at death from company B and overall.

For most of the job groups the observed and expected deaths were approximately the same. There was a deficit overall for security men and from company C. There was a slight excess for general

manual workers from company C but a deficit for general manual workers from company A. An excess was found for craftsmen from company A. The ratio of observed over expected deaths tended to increase with later cohort of entry with a pronounced excess at company B for those joining in 1960 or after. The ratio of observed over expected deaths also tended to increase with increasing length of service with an excess in company B for men with 15–19 years' service and a slight excess in company A.

The analyses shown in table 4 showed some excesses in subgroups of the population that required further investigation. Table 5 gives the results of further analyses by age, job, and reason for leaving for men joining company B in or after 1960. Table 6 gives similar results for men from company B with 15–19 years' service. (The two excesses in company B were mutually exclusive—that is, none of those starting in 1960 had worked 15 years and all those with 15–19 years' service joined before 1960.)

In the cohort of those who joined in or after 1960 two thirds were aged under 55 at death, a pronounced excess. The observed deaths were more than those expected for all job groups except supervisors, although none of the excesses was statistically significant. There were also more observed deaths than expected in subgroups defined by when the death occurred (in service, after retirement, after leaving for other reasons), with an excess in those leaving for other reasons. Of the 18 "other leavers," 15 had worked under five years. Of the 37 deaths in service or after retirement, 27 had worked five or more years.

Table 5 *Observed deaths (O), expected deaths (E), O/E, and p values from ischaemic heart disease for men in company B who started work in 1960 or after*

Subgroup	*O*	*E*	*O/E*	*p*
No	55	39·86	1·38	0·01
Age:				
<45	15	11·71	1·28	0·20
45–54	25	15·37	1·63	0·01
55–64	8	8·79	0·91	0·48
65–74	7	3·32	1·83	0·09
≥75	—	0·17	—	0·84
Job:				
Operator	15	10·92	1·37	0·14
Driver	17	14·17	1·20	0·26
Craftsmen	3	2·34	1·28	0·41
General manual worker	7	4·25	1·65	0·14
Security	4	1·82	2·20	0·11
Administrator	9	5·51	1·63	0·11
Supervisor	—	0·85	—	0·43
Reason for leaving				
Died	31	25·80	1·20	0·18
Retired	6	3·98	1·51	0·21
Other	18	10·08	1·79	0·02

Table 6 *Observed deaths (O), expected deaths (E), O/E, and p values from ischaemic heart disease for men in company B with 15–19 years' service*

Subgroup	*O*	*E*	*O/E*	*p*
No	114	93·09	1·22	0·02
Age:				
<45	12	6·12	1·96	0·02
45–54	36	22·48	1·60	<0·01
55–64	31	33·09	0·94	0·40
65–74	26	26·38	0·99	0·52
≥75	9	5·02	1·79	0·07
Job:				
Operator	24	21·62	1·11	0·33
Driver	56	39·01	1·44	<0·01
Craftsman	7	6·03	1·16	0·40
General manual worker	9	7·26	1·24	0·31
Security	6	5·49	1·09	0·47
Administrator	8	7·43	1·08	0·47
Supervisor	4	6·25	0·64	0·25
Reason for leaving:				
Died	39	31·99	1·22	0·13
Retired	45	39·08	1·15	0·19
Other	30	22·00	1·36	0·06

There was also a pronounced excess in men aged under 55 at death for those with 15–19 years' service. There were more deaths observed than expected in all job groups except supervisors with a pronounced excess for drivers. Once again there were more deaths observed than expected for all categories defined by reason for leaving.

DEATHS FROM MALIGNANT DISEASE

Mortality from all neoplasms (table 7) was significantly lower than expected as was mortality from cancer of the lung. Deficits of observed deaths compared with those expected were found for cancer of the oesophagus, intestines, and bladder, and to a lesser extent for cancer of the stomach.

The lowered mortality overall for all neoplasms and cancer of the lung was found in particular in companies B and C and in several job groups. The ratio of observed to expected deaths tended to decrease with later cohort of entry for all neoplasms, especially in company B where there was an excess for men joining in 1960 or after ($O = 43$, $E = 32{\cdot}78$, $p \leq 0{\cdot}05$). This was accounted for by an excess in this group from lung cancer ($O = 19$, $E = 11{\cdot}67$, $p < 0{\cdot}05$). There was also an excess from lung cancer for men in company B with under five years' service ($O = 34$, $E = 24{\cdot}37$, $p < 0{\cdot}05$). Of these 34 deaths, 25 had left for reasons other than death or retirement. Only three of these 25 died within five years of leaving and 15 died 10 years or more after leaving.

Mortality from all neoplasms of the lymphatic and

Table 7 *Observed and expected deaths, O/E, and p values for all neoplasms and malignant causes with five or more observed deaths for workers employed in oil distribution centres in Britain from 1 January 1950 to 31 December 1975*

Cause (ICD order)	*Observed deaths*	*Expected deaths*	*O/E*	*p*
All neoplasms	1002	1156·70	0·87	<0·0001
Cancer of mouth and tonsils	5	4·82	1·04	0·53
Cancer of pharynx	7	6·25	1·12	0·43
Cancer of oesophagus	17	28·09	0·61	0·02
Cancer of stomach	123	144·47	0·85	0·08
Cancer of intestines	57	71·75	0·79	0·04
Cancer of rectum	57	53·60	1·06	0·34
Cancer of liver and gall bladder	15	20·55	0·73	0·13
Cancer of pancreas	39	46·89	0·83	0·14
Cancer of lung and pleura	384	482·83	0·80	<0·0001
Cancer of skin (excluding scrotum)	5	8·52	0·59	0·15
Cancer of prostate	53	48·57	1·09	0·28
Cancer of testes	6	5·01	1·20	0·39
Cancer of urinary bladder	32	42·83	0·75	0·05
Cancer of kidneys and suprarenals	23	19·05	1·21	0·21
Cancer of brain and other parts of central nervous system	39	36·54	1·07	0·36
Lymphosarcoma	7	8·05	0·87	0·45
Hodgkin's disease	17	12·20	1·39	0·11
Other neoplasms lymphoid tissue	6	3·63	1·65	0·16
Multiple myeloma	11	9·37	1·17	0·34
Leukaemia	28	26·82	1·04	0·44
Myelofibrosis	5	1·81	2·76	0·04

haematopoietic tissue (ICD 8th revision 200–208) plus myelofibrosis (ICD 209) was slightly raised overall (O = 77, E = 68·46, p = 0·30) and in six of the eight individual neoplasms making up this disease group. With the exception of reticulum cell sarcoma, where there were only two deaths observed (E = 5·56, p = 0·08), excesses of observed deaths were found for all these neoplasms in subgroups of the study population, although they are all based on small numbers of deaths. These excesses included: Hodgkin's disease in drivers overall (O = 9, E = 4·96, p = 0·07); other neoplasms of the lymphoid tissue in company C (O = 5, E = 1·14, p = 0·01) and in operators overall (O = 3, E = 0·74, p = 0·04); multiple myeloma in operators from company B (O = 4, E = 1·14, p < 0·05); leukaemia in supervisors overall (O = 6, E = 2·80, p = 0·07) and men starting before 1940 from company B (O = 15, E = 7·76, p < 0·01); and myelofibrosis in company B (O = 4, E = 1·05, p < 0·05). In an analysis of the deaths from leukaemia by histological type an excess from chronic lymphatic leukaemia was found in company B (O = 8, E = 3·43, p < 0·05) (comparison rates by histological type for the only available quinquennium 1971–5 were used for all calendar period groups). The observed deaths from acute myeloid leukaemia (9), which has been particularly associated with exposure to benzene, approximately equalled those expected (9·91).

Discussion

The patterns of mortality were not consistent in the three companies studied but the data sources and the composition of the population were rather different. The information for company C was taken mainly from pension records, and records for men leaving for reasons other than death or retirement were mostly unavailable. An appreciable number of men from company C were therefore not included in the study. These leavers, however, were likely to have been younger and with shorter service than men who had retired or died in service. They would be likely to contribute comparatively fewer deaths to the study than the other two groups of leavers.[26] It is also not clear whether all men from company C who died in service were eligible for a pension and were thus included in the study. For example, in company B the deaths in service constituted about a third of the total of all deaths in service and after retirement compared with only a quarter in company C.

In company A a larger proportion of the men left for reasons other than death or retirement than in the other two companies. (These men were generally young when they left and had short service.) This may be because company A took over several small companies that had had a relatively quick turnover of employees. These differences may contribute to some extent to the non-comparability of the results between the companies.

Some of the limitations of this type of study and the problems inherent in interpreting the results have been discussed in our previous report on the refinery workers.[1] These include inaccuracy in diagnosis, classification, and coding of the causes of death, and omission of information from the death details; the identification of the true "occupational"

hazard when many comparisons of observed and expected deaths are made; small numbers in the study; and short period of follow up. The detailed examination of the data has been used to describe the patterns of mortality and to search for consistency across the subgroups of the population.

Other factors that may influence variations in mortality include (*a*) use of inappropriate rates in calculating the expected deaths, (*b*) varying patterns of diagnosis and certification in different regions, (*c*) variation in the observed deaths due to chance, (*d*) external (non-occupational) factors such as the lifestyle of those in the study population influencing the mortality patterns, and (*e*) an occupational environmental factor influencing the mortality risk.

Overall the mortality of the study population is much lower than that of the standard population with which it was compared. This result may be due to the comparison of an industrially employed cohort with a standard population that includes those in unstable employment and the chronically ill and disabled. This reduction in comparison with deaths expected from national mortality rates is the usual finding in such studies—for example, the refinery and London Transport studies.

This low overall mortality usually extends to the broad causes of death responsible for large numbers of deaths, particularly the non-malignant causes. Table 8 gives the ratios of observed over expected deaths for all causes of death and three numerically large causes of death separately for the distribution centre, refinery, and London Transport studies. These ratios are based on large numbers of deaths and chance fluctuations may be excluded. All the ratios are low except that for ischaemic heart disease in the distribution workers. This result seems out of line on examination of both the data from these three studies and also in relation to published comparative studies. In addition, ratios for lung cancer in both the refinery study and distribution centre study are low (0·78 and 0·80 respectively). It was suggested that the refinery results might be, in part, due to reduction in smoking by the men in comparison with the general population—smoking is one of the known aetiological factors for the three causes of death shown in table 8.

Table 8 *Comparison of the ratio of observed deaths over expected deaths for main causes of death in the three studies carried out*

	Refineries	*Distribution centres*	*London Transport Executive*
All causes	0·84	0·85	0·84
Cerebrovascular disease	0·90	0·87	0·78
Ischaemic heart disease	0·90	0·99	0·74
Bronchitis	0·64	0·67	0·77

These points suggest that the result for the distribution centre for ischaemic heart disease is unexpected. The overall mortality from this cause is not higher than in the general population but is not reduced as one would have expected from the other results. This prompted a particular scrutiny of subgroups of the distribution centre workforce to check for any evidence that mortality was increased over the ratio of 0·90, the typical finding. As described above several excesses of observed deaths were found in subgroups of the population, particularly in company B.

In the refinery study it has been shown that low mortality overall and from numerically large non-malignant causes is particularly pronounced for deaths in service but that the ratio of observed over expected deaths tends to approach or exceed unity—that is, the healthy worker effect disappears—for both deaths after retirement and deaths after leaving for other reasons.[26] The disappearance of the healthy worker effect for the latter group of relatively young, short service men suggested that they differed from the stable workforce both in employment history and in aspects (albeit unknown) of their lifestyle. In the distribution centre study the same pattern was generally found, including mortality from ischaemic heart disease. The analyses in tables 5 and 6 also show this higher mortality for the "other leavers." Unlike the other large disease groups, however, there is no significant deficit from ischaemic heart disease for deaths in service from company B and the observed deaths (227) approximately equal those expected (231·64). This again is an unexpected result.

The healthy worker effect consists of two parts, the selection effect and the survival effect.[27] It has been suggested that many of the distribution centre study population started work before the introduction of pre-employment medical examinations and before heavy goods vehicles licenses were required. It has been pointed out, however, that many men were previously employees of the Petroleum Board which would have required some overall standard of health. There is no suggestion that the procedure of selection of a healthy workforce is likely to be different for ischaemic heart disease than for other diseases, such as hypertensive disease or respiratory disease, where a healthy worker effect was observed. The survival effect therefore may differ in this study population, particularly for company B for ischaemic heart disease, perhaps due to a difference in lifestyle or to an occupational risk. The data are not sufficiently detailed in this particular study, however, to follow this issue further.

The expected deaths were not adjusted to take account of regional or social class variation in mortality. As the centres were scattered throughout Britain it was thought that any regional differences in mortality balanced out overall. There were three excesses found in non-malignant disease groups for general manual workers—cerebrovascular disease, other diseases of the circulatory system, asthma, and an excess from bronchitis for security men. These, however, were not greater than expected compared with all men of the appropriate social class. The standardised mortality ratios for ischaemic heart disease increased from 88 in social class I to 111 in social class V.[28] The conclusions drawn from the results described above, however, would not differ if adjustments were made using these figures.

Most of the other excesses from non-malignant disease groups occurred in isolated subgroups of the population and were mainly based on small numbers of deaths. There is no evidence that any of these were occupational in origin.

Mortality from all neoplasms was much lower than expected, especially for drivers, craftsmen, administrators, and supervisors. Mortality from lung cancer was also much lower overall and in these job groups. Mortality from all neoplasms tended to increase with later cohort of entry overall, especially in company B with an excess for those men joining this company in 1960 or after. This was accounted for by an excess in lung cancer for men from company B with less than five years' service. An absence of heavy smokers, perhaps due to the restrictions of smoking demanded by the nature of the work, might account for the general low mortality from lung cancer. Those who left with under five years' service were usually young and presumably went to other occupations. Most died several years after leaving the oil company. Possibly the smoking habits of these men differed from the more stable workforce, but there are no reliable data with which to investigate this.

Unlike the refinery study[1] mortality from cancer of the gastrointestinal tract was not increased and the overall mortality from this was significantly lower than expected. There were conflicting results for drivers for stomach cancer with an excess in company C and a deficit in company B. There was also no raised mortality from either melanoma or cancer of the nasal cavities and sinus, both of which showed excesses in the refinery study. There was no excess of observed deaths from epithelioma and no deaths at all from scrotal cancer, both of which have been shown in previous studies to be associated with contact with mineral oil.[9 10]

Other work indicated the need to look carefully at the mortality from leukaemia and the other neoplasms of the lymphatic and haematopoietic tissue.[2 11 13 29] In the distribution centre study there were slightly more deaths observed than expected from all neoplasms of the lymphatic and haematopoietic tissue. For all men in the study none of the seven specific forms of neoplasm examined shows a significant increase. There were slightly more deaths observed than expected overall for leukaemia and approximately the same number of deaths observed as expected from acute myeloid leukaemia, which has been particularly associated with exposure to benzene. There was, however, an excess of deaths from chronic lymphatic leukaemia in men from one company with long service. There were excesses in subgroups of the study population in most of the other diseases making up diseases of the lymphatic and haematopoietic tissue. There was also an excess from myelofibrosis which is an associated disease. These diseases are rare and the numbers of deaths, even with such a large study population as the distribution centre study, are likely to be small. The identification of the causative factors of these diseases is thus made even more difficult.

A large number of distribution centres were included in this study. The numbers of men and numbers of deaths from each centre were thus rather small for a formal analysis. Nevertheless, there was no indication from an informal examination of the deaths by distribution centre that any individual centre was particularly concerned. Inspection of the material did not show any clustering of results in neighbouring distribution centres within the same region.

A comparison of the results found in this study with published national occupational mortality data is not really feasible as the classifications used by the Registrar General, such as welder, boilermaker, engineer, do not distinguish the industry in which such men work. As in the refinery study process workers are included in the classification "chemical production process workers not elsewhere classified." Death rates for men aged 15–64 in this group were slightly higher than for all men of this age group[28] but the difference disappeared when social class standardisation was carried out. An excess of stomach cancer was also found, but was partially removed by social class standardisation.

Drivers are included in the classification "drivers of road goods vehicles." The SMR for men aged 15–64 in this group was 111 but fell to 106 when social class was taken into account. Excesses were found for motor vehicle accidents, cancer of the stomach, and lung cancer. The excess from lung cancer remained significant when social class was taken into account and was associated with an excess from bronchitis, emphysema, and asthma. It was

suggested in the *Occupational Mortality Decennial Supplement* that this was the "result of social habits such as smoking which were probably adopted more often or to a greater degree by men in this classification than by other men in the same social class." In the present study deaths from cancer of the lung, bronchitis, emphysema, and asthma are much lower than expected overall and for drivers. This suggests that smoking may be lower in the study population than in men of the same social class or occupational unit. By contrast, ischaemic heart disease, which is also related to smoking, shows no lowered mortality.

Conclusions

The analyses of the distribution centre data suggest that consideration might be given to further study of both ischaemic heart disease and diseases of the lymphatic and haematopoietic tissue. The information collected, however, was limited in respect of both the details collected on each man and the length of follow up. Various methods of follow up that could be considered when assessing the results of this study include carrying out a prevalence survey to investigate ischaemic heart disease using a questionnaire to obtain details of symptoms such as angina and taking physical measurements—for example, using an ECG; carrying out case-control studies using internally matched controls and examining information about job history and other environmental factors—this would be appropriate for investigating both prevalent cases of heart disease and deaths from ischaemic heart disease and neoplasms of the lymphatic and haematopoietic tissue; extending the duration of follow up of the study to establish whether the mortality patterns found in 1950–75 continue, although a minimum of a further 10 years' follow up would be required; and investigating whether the collection of environmental measures and detailed job history information could provide more precise indicators of exposure to relate to the incidence of the various diseases.

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Requests for reprints to: Dr L Rushton, Thames Polytechnic, School of Mathematics, Statistics and Computing, Wellington Street, London SE18 6PF.

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[2] Soter NA, Wasserman SI, Austen KF. Cold urticaria: release into the circulation of histamine and eosinophil chemotactic factor of anaphylaxis during cold challenge. *N Engl J Med* 1976;**294**:687-90.
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