# Further follow up of mortality in a United Kingdom oil distribution centre cohort

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**Abstract**

**Results of an extension of follow up (1976 to 1989) of a cohort of workers employed for at least one year between 1 January 1950 and 31 December 1975 at oil distribution centres in Britain are presented. Over 99% of the workers were successfully traced to determine their vital status at 31 December 1989. The mortality observed was compared with that expected from the death rates of all the male population of England and Wales. The mortality from all causes of death for the total study population was less than that of the comparison population, and reduced mortality was also found for many of the major non-malignant causes of death. No healthy worker effect was found for ischaemic heart disease, and raised mortality from this disease was found in particular for one company and in several job groups. Raised mortality was also found for aortic aneurysm. Mortality from all neoplasms was lower than expected overall, largely due to a deficit of deaths from malignant neoplasm of the lung. Raised mortality patterns from all neoplasms, malignant neoplasm of the lung, and several non-malignant disease groups were found for general manual workers although the mortality from many of these diseases for all men in this social class in the national population is also high. There was increased mortality from malignant neoplasms of the larynx and prostate but these tended to be in isolated subgroups. Mortality from malignant neoplasm of the kidney was raised overall and in drivers in particular. Mortality from leukaemia was high at one company and in drivers overall.**

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Previous publications[1 2] have reported the initial follow up from 1951 to 1975 of employees at United Kingdom oil distribution centres. This paper describes the results of extending this follow up to 31 December 1989. The detailed results for kidney cancer and leukaemia are reported elsewhere.[3]

A review of previous reports documenting the carcinogenic properties of oil, and mortality and morbidity studies of oil refinery populations and resident populations in areas where the petroleum industry is concentrated is given in another paper.[4] There have been few studies of workers at oil distribution centres although they have been included in some broader studies of the oil industry.[5-7] Harrington[8] reviewed the petroleum manufacturing industry and the distribution industry for all diseases. Christie[7] found lower mortality for terminal workers from all causes and all malignant neoplasms but an excess incidence from all lymphatic and haematopoietic cancers.

Several studies have examined exposure to oil mist with particular concern for bronchial carcinoma and other respiratory diseases. Conflicting results have been reported for lung cancer. No excesses were found in some studies[9-11] but others reported excesses—namely, in the printing industry[12 13] and in cable manufacture.[14]

Several studies have carried out personal air sampling or taken urine samples to investigate the exposure of workers to benzene at bulk marketing terminals[15 16] or service stations.[16-19] A proportional mortality (PMR) study[20] of all deaths over a 10 year period in New Hampshire found high PMRs for service station workers for leukaemia, suicide, emphysema, and mental conditions. De Silva[21] measured blood lead concentrations of petrol pump attendants in Melbourne and concluded that the concentrations were lower than those accepted as a cause of concern.

Knave *et al*[22] found a higher incidence of acute neurological and psychiatric symptoms in workers heavily exposed to jet fuel in a jet motor factory compared with non-exposed workers. Other studies have looked at the effect of diesel exhaust emissions.[23 24] Wong *et al* found increased mortality from cancer of the liver, emphysema, and accidents

in a cohort of members of a heavy construction operators union but no significant findings when exposure to diesel exhaust was examined.[25]

## Results of the Institute of Petroleum study, follow up 1951-75

The overall mortality in the previously reported results for the Institute of Petroleum (IP) distribution study follow up to 1975[1] was much lower than expected as was the mortality from stroke, hypertensive disease, bronchitis, and pneumonia. A deficit of all neoplasms and lung cancer was found. The observed deaths from ischaemic heart disease were roughly equal to those expected and there was no evidence of a healthy worker effect. 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.

## Methods

Full details of the feasibility study carried out before the initial collection of data, the reasoning behind the choice of data, items to be collected, and the methods used are given in earlier publications.[1 2] Briefly, the study included all men with a duration of service of at least one continuous year between 1 January 1950 and 31 December 1975 at distribution centres from three companies in the United Kingdom, including airports and blending plants. In this paper the three companies are denoted by I, II, and III.

The data collected, the procedures of flagging and tracing the population, the coding of the multiple causes of death, and the calculation of expected deaths were, in general, the same as those for the Institute of Petroleum refinery study described elsewhere.[4] A similar approach to the analysis has been taken—namely, the use of the standardised mortality ratio (SMR) and its 95% confidence interval (95% CI) to examine the magnitude and patterns of mortality. The same caveats on the interpretation of results from this type of study also apply.

Unlike the refinery study, data on shift patterns were not collected for the distribution centre population. The only data that were reliably available for company III were for those in service on 1 January 1976, deaths in service, and pensioners. Little information was collected on deferred pensioners or others who left this company.

When most of the flagging had been completed an examination of the records for those leaving before 1 January 1976 showed that, as in the refinery study, there was a larger proportion of the older distribution study population flagged as alive at 31 December 1989, compared with the proportion in the population of England and Wales—for example, 10% were older than 75 compared with 5% older than 75 in the population of England and Wales. Tracing these men (about 2000) through the National Insurance records yielded 150 further deaths.

As in the analysis of the first follow up,[1 2] the expected deaths were calculated by applying the five year age and calendar period specific death rates for England and Wales to the five year age and calendar period person-years at risk in the study cohort. As the distribution centres were well scattered throughout the United Kingdom it was decided, as before, not to separate the data into Scotland and 10 standard regions in England and Wales, as the numbers would be reduced too much for analysis. No formal adjustment was made to take account of known variations in death rates by social class or region but these have been used to aid the interpretation of the results.

## Results

Table 1 shows the vital status of the total study population at 31 December 1989. As before no traces have not been included in the analyses. Included in the alive group were 1004 men whom it was not possible to flag with the National Health Service Central Registers (NHSCRs) but who have been traced as alive at 31 December 1989 through the National Insurance records. Those who emigrated have been taken as alive up to the date of emigration, this date therefore being their study end date. Like the refinery study, more emigrations have been identified than in the previous tracing exercise due to all records having been sent to the NHSCRs for flagging.

The identification of the study population at the distribution centres was not as complete as that of the refinery population—for example, addresses were often not available. This has resulted in a slightly higher proportion than in the refinery study, of untraced persons and men who, although untraced through the NHSCRs, have been found to be alive through the National Insurance records.

The dead include 66 for whom it was not possible to obtain a death certificate, 26 known to have died abroad, and 40 identified as dead from the National Insurance records but for whom no trace was found either in the English or Scottish

*Table 1 Vital status of the distribution centre population at 31 December 1989*

| *Company* | *Alive* | *Dead* | *Emigrated* | *No trace* | *Total* |
|---|---|---|---|---|---|
| I | 1303 | 643 | 29 | 8 | 1983 |
| II | 9464 | 5458 | 209 | 52 | 15183 |
| III | 3401 | 2642 | 59 | 38 | 6140 |
| Total | 14168 | 8743 | 297 | 98 | 23306 |

*Table 2 Person-years of observation of distribution centre population*

| Company | Person years of observation | |
|---|---|---|
| | *At 31 December 1975* | *At 31 December 1989* |
| I | 30644 | 51679 |
| II | 261612 | 413464 |
| III | 105313 | 161328 |
| Total | 397569 | 626471 |

*Table 3 Population of the distribution centres by job classification*

| *Job title* | *No (%)* |
|---|---|
| Operator | 4705 (20·2) |
| Driver | 10108 (43·4) |
| General manual worker | 1612 (6·9) |
| Supervisor | 1685 (7·2) |
| Craftsman | 1594 (6·8) |
| Administrative and clerical | 3134 (13·5) |
| Security | 467 (2·0) |
| Total | 23306 (100·0) |

death certificate records or the company pension records. In the analyses these 66 records were taken as dead, cause unknown.

Table 2 shows the person-years of observation for the total study population and for each company, an increase of about 230 000 person-years overall.

The information collected about job was the last job title for those who had left the distribution centres or the current title for those in post. Table 3 gives the distribution of the study population by job title. The largest group was drivers (just under a third of the total population), followed in size by operators and clerical, administration, and managerial workers. These broad job groupings covered differences in classification of jobs over the 25 year study period and also differences between the companies. Two classifications, general manual worker and security, seemed to have gone out of use in all the companies as only a handful of men in employment at 1 January 1976 had these titles.

Analyses by year of starting work and years since first employment, the second being a measure of exposure, were carried out, although small numbers in some disease groups made the patterns of mortality unclear.

## NON-MALIGNANT CAUSES OF DEATH

Table 4 gives the observed and expected deaths, the SMRs, and the 95% CIs for the SMRs for all causes of death and for non-malignant causes of

*Table 4 Observed (O) and expected (E) deaths, SMRs, and 95% CIs for non-malignant causes of death*

| | *Follow up 1951–75* | | | | *Follow up 1976–89* | | | | *Follow up 1951–89* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cause of death* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* |
| All causes | 3964 | 4547·1 | 87 | (84–90) | 4779 | 5052·9 | 95 | (92–97) | 8743 | 9600·0 | 91 | (89–93) |
| Respiratory TB | 12 | 48·6 | 25 | (13–43) | 5 | 7·8 | 64 | (21–150) | 17 | 56·4 | 30 | (18–48) |
| Diabetes | 19 | 25·9 | 73 | (44–115) | 27 | 45·6 | 59 | (39–86) | 46 | 71·5 | 64 | (47–86) |
| Anaemias | 8 | 6·8 | 118 | (51–232) | 11 | 12·0 | 92 | (46–164) | 19 | 18·8 | 101 | (61–158) |
| Cerebrovascular disease | 376 | 418·6 | 90 | (81–99) | 450 | 463·6 | 97 | (88–106) | 826 | 882·2 | 94 | (87–100) |
| Chronic rheumatic heart disease | 35 | 58·3 | 60 | (42–83) | 14 | 20·0 | 70 | (38–117) | 49 | 78·3 | 63 | (46–83) |
| Ischaemic heart disease | 1398 | 1359·3 | 103 | (98–108) | 1639 | 1666·7 | 98 | (94–103) | 3037 | 3026·0 | 100 | (97–104) |
| Other heart disease | 72 | 106·6 | 68 | (53–85) | 135 | 148·3 | 91 | (76–108) | 207 | 254·9 | 81 | (71–93) |
| Hypertensive heart disease | 65 | 90·1 | 72 | (56–92) | 30 | 42·2 | 71 | (48–101) | 95 | 132·3 | 72 | (58–88) |
| Diseases of the arteries | 84 | 86·2 | 97 | (78–121) | 154 | 140·8 | 109 | (93–128) | 238 | 227·0 | 105 | (92–119) |
| Other circulatory disease | 37 | 35·2 | 105 | (74–145) | 27 | 27·9 | 97 | (64–141) | 64 | 63·1 | 101 | (78–130) |
| Influenza | 13 | 25·4 | 51 | (27–88) | 2 | 6·2 | 32 | (4–117) | 15 | 31·6 | 48 | (27–78) |
| Pneumonia | 135 | 181·6 | 74 | (62–88) | 241 | 263·7 | 91 | (80–104) | 376 | 445·3 | 84 | (76–93) |
| Bronchitis and emphysema | 240 | 349·0 | 69 | (60–70) | 160 | 208·0 | 77 | (65–90) | 400 | 557·0 | 72 | (65–79) |
| Asthma | 15 | 15·1 | 99 | (56–164) | 9 | 11·3 | 80 | (36–151) | 24 | 26·4 | 91 | (58–135) |
| Peptic ulcer | 42 | 49·8 | 84 | (61–114) | 27 | 38·0 | 71 | (47–103) | 69 | 87·8 | 79 | (61–99) |
| Cirrhosis of liver | 9 | 17·3 | 52 | (24–99) | 13 | 25·1 | 52 | (28–89) | 22 | 42·4 | 52 | (33–79) |
| Nephritis and nephrosis | 15 | 31·9 | 47 | (26–78) | 6 | 7·9 | 76 | (28–165) | 21 | 39·8 | 53 | (33–81) |
| Hyperplasia of the prostate | 11 | 15·8 | 70 | (35–125) | 10 | 11·1 | 90 | (43–166) | 21 | 26·9 | 78 | (48–120) |
| Motor vehicle accidents | 75 | 68·5 | 109 | (86–137) | 25 | 31·1 | 80 | (52–119) | 100 | 99·6 | 100 | (82–122) |
| Accidental falls | 17 | 23·8 | 71 | (42–114) | 16 | 23·1 | 69 | (40–112) | 33 | 46·9 | 70 | (48–99) |
| Accidental fire and explosion | 7 | 4·1 | 171 | (69–352) | 4 | 4·1 | 98 | (27–250) | 11 | 8·2 | 134 | (67–239) |
| Suicide | 38 | 66·2 | 57 | (41–79) | 27 | 38·2 | 71 | (47–103) | 65 | 104·4 | 62 | (48–79) |

death for the total distribution centre population, for the first follow up 1951–75, the second follow up 1976–89, and the total follow up periods.

The SMR for all causes was higher in the second follow up period than in the first but was still very low, indicative of a continuation of the healthy worker effect. A similar pattern was shown for many of the numerically large non-malignant causes of death, such as cerebrovascular disease, other heart disease, diseases of the arteries, pneumonia, and bronchitis. The largest non-malignant disease group, ischaemic heart disease, showed increased mortality in the first follow up period but the observed value in the second period was less than that expected giving an SMR of 100 for the total follow up. Only diseases of the arteries, other circulatory disease, and accidental fire and explosion had SMRs greater than 100 for the total follow up period.

Table 5 gives the observed and expected deaths, SMRs, and 95% CIs by time since first employment for selected causes of death. The tendency was for the mortality from the numerically large non-malignant disease groups to increase with increasing time since first employment up to 40 years, and to increase up to year of entry (1950–4) and then decline.

The low overall healthy worker effect was not reflected in the results for company I and there was a tendency for the total population from this company to have higher SMRs than the other companies for the non-malignant disease groups. Mortality was raised for motor vehicle accidents (O = 77, E = 64·9, SMR=119, 95% CI 94–148) at company II, and diseases of the arteries at company I (O = 24, E = 14·5, SMR = 165, 95% CI 106–246), and there were slightly more observed deaths than expected for ischaemic heart disease at company II (O = 1916, E = 1878·4, SMR = 102, 95% CI 97–107).

With the exception of ischaemic heart disease and diseases of the arteries there were no increased mortality patterns for drivers, craftsmen, supervisors, and administrative, clerical, and managerial staff overall or for the non-malignant disease groups. The mortality from all causes was raised overall for security men, particularly at company II (O = 284, E = 260·8, SMR = 109, 95% CI 97–122). The mortality from bronchitis was increased appreciably, overall for this job group (O = 45, E = 30·3, SMR = 149, 95% CI 108–199) and was raised for all three companies.

Table 6 lists SMRs for all causes of death by company and for cause and company combinations greater than 100 for general manual workers. Mortality was raised overall and most of the numerically large non-malignant disease groups showed increased mortality. Mortality from cerebrovascular disease was raised, particularly at company III (O = 25, E = 15·5, SMR = 162, 95% CI 105–239), and ischaemic heart disease, particularly at company II (O = 151, E = 132·5, SMR = 114, 95% CI 96–134) and company III (O = 52, E = 40·5, SMR = 128, 95% CI 96–168).

Two non-malignant disease groups showed consistently raised mortality patterns across several of the subgroups analysed—namely ischaemic heart disease (International Classification of Diseases (ICD)—9th revision 410–414) and diseases of the arteries (ICD—9th revision 440–448). Table 7 shows the results for ischaemic heart disease. Mortality was increased at company II in operators, general manual workers, and clerical, administrative, and managerial staff. The SMRs were particularly raised for men aged between 45 and 55 at death and for those aged 65 to 74. Mortality

*Table 5 Observed (O) and expected (E) deaths, SMRs and 95% CIs for selected causes by time since first employment*

| | *Time since first employment (y)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0–9* | | | | *10–19* | | | | *20–29* | | | |
| *Disease* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* |
| All causes | 383 | 481·2 | 80 | (72–88) | 1044 | 1196·5 | 87 | (82–93) | 1741 | 1933·9 | 90 | (86–94) |
| All malignant neoplasms | 115 | 115·0 | 100 | (83–120) | 324 | 317·1 | 102 | (91–114) | 481 | 532·5 | 90 | (82–99) |
| Malignant neoplasm of stomach | 12 | 13·3 | 90 | (40–157) | 44 | 33·8 | 130 | (95–175) | 48 | 54·4 | 88 | (65–117) |
| Intestine | 4 | 7·0 | 57 | (16–146) | 12 | 19·8 | 60 | (31–106) | 35 | 33·7 | 104 | (72–144) |
| Rectum | 5 | 4·8 | 103 | (34–241) | 9 | 14·1 | 64 | (29–121) | 18 | 24·2 | 74 | (44–118) |
| Larynx | 1 | 1·02 | 98 | (2–546) | 7 | 3·1 | 227 | (91–469) | 9 | 5·3 | 169 | (77–320) |
| Lung | 47 | 41·4 | 113 | (83–151) | 119 | 126·0 | 94 | (78–113) | 194 | 216·2 | 90 | (78–103) |
| Prostate | 4 | 1·9 | 210 | (57–538) | 12 | 9·0 | 133 | (68–232) | 23 | 23·2 | 99 | (63–149) |
| Kidney | 2 | 2·2 | 90 | (11–325) | 7 | 6·6 | 106 | (43–219) | 8 | 10·6 | 75 | (33–149) |
| Leukaemia | 3 | 4·7 | 64 | (13–188) | 9 | 8·7 | 103 | (47–196) | 14 | 11·9 | 117 | (64–197) |
| Cerebrovascular disease | 15 | 30·6 | 49 | (27–81) | 73 | 87·2 | 84 | (66–105) | 136 | 154·8 | 88 | (74–104) |
| Ischaemic heart disease | 113 | 121·6 | 93 | (77–112) | 367 | 387·8 | 95 | (85–105) | 665 | 649·5 | 102 | (95–110) |
| Diseases of the arteries | 3 | 5·0 | 60 | (12–176) | 15 | 18·1 | 83 | (46–137) | 35 | 38·5 | 92 | (64–127) |
| Pneumonia | 6 | 12·4 | 48 | (18–105) | 32 | 35·3 | 91 | (62–128) | 53 | 67·9 | 78 | (58–102) |
| Bronchitis | 20 | 22·6 | 89 | (54–137) | 41 | 62·4 | 66 | (47–89) | 64 | 101·9 | 63 | (48–80) |

*Table 6 Observed (O) and expected (E) deaths, SMRs, and 95% CIs for general manual workers for selected disease and company subgroups*

| *Cause of death* | *Company* | *O* | *E* | *SMR* | *(95% CI)* |
|---|---|---|---|---|---|
| All causes | I | 99 | 101·1 | 98 | 80–119 |
| | II | 489 | 426·4 | 115 | 105–125 |
| | III | 158 | 140·4 | 113 | 96–132 |
| | Total | 746 | 667·8 | 112 | 104–120 |
| All neoplasms | II | 133 | 107·7 | 123 | 103–146 |
| | Total | 187 | 166·0 | 113 | 97–130 |
| Malignant neoplasm of the lung | II | 57 | 42·0 | 136 | 103–176 |
| | Total | 77 | 65·2 | 118 | 93–148 |
| Diabetes | Total | 10 | 4·8 | 209 | 100–385 |
| Cerebrovascular disease | Total | 80 | 64·1 | 125 | 99–155 |
| Ischaemic heart disease | Total | 225 | 205·0 | 110 | 96–125 |
| Peptic ulcer | Total | 12 | 6·4 | 189 | 98–330 |
| Motor vehicle accidents | Total | 13 | 7·6 | 172 | 91–294 |

*Table 7 Observed (O) and expected (E) deaths, SMRs, and 95% CIs for ischaemic heart disease by company and other subgroups*

| *Subgroup* | *O* | *E* | *SMR* | *(95% CI)* |
|---|---|---|---|---|
| Company: | | | | |
| I | 220 | 211·4 | 104 | (91–119) |
| II | 1916 | 1878·4 | 102 | (97–107) |
| III | 901 | 936·2 | 96 | (90–103) |
| Total | 3037 | 3026·0 | 100 | (97–104) |
| Age: | | | | |
| <45 | 94 | 90·4 | 104 | (84–127) |
| 45–54 | 458 | 403·4 | 114 | (103–124) |
| 55–64 | 864 | 872·2 | 99 | (93–106) |
| 65–74 | 1044 | 996·4 | 105 | (99–111) |
| ⩾75 | 332 | 364·9 | 91 | (81–101) |
| Job: | | | | |
| Operator | 655 | 625·2 | 105 | (97–113) |
| Driver | 1172 | 1172·4 | 100 | (94–106) |
| Craftsman | 187 | 194·3 | 96 | (83–111) |
| General manual worker | 225 | 205·0 | 110 | (96–125) |
| Security man | 98 | 110·5 | 89 | (72–108) |
| Administrative/clerical/ managerial | 412 | 396·5 | 104 | (94–114) |
| Supervisor | 288 | 318·2 | 91 | (80–102) |

increased with increasing calendar period of follow up until 1975 and then declined.

The raised mortality patterns from diseases of the arteries were not as pronounced as those in the refinery study.[4] The observed deaths overall were more than those expected (see table 4), and mortality was also raised for operators (O = 52, E = 45·1, SMR=115, 95% CI 86–151) and for administrative, clerical, and managerial staff (O = 34, E = 29·2 SMR = 116, 95% CI 81–163).

Of the 238 deaths from the broad disease category, diseases of the arteries, 60 were from atherosclerosis (E = 71·9, SMR = 83, 95% CI 64–107) and 133 were from aortic aneurysm.

Table 8 gives results for aortic aneurysm by company, age, and selected subgroups. The raised mortality from diseases of the arteries was due mainly to raised mortality from aortic aneurysm; this was high in companies I and III in particular. Mortality was increased slightly at all ages after 60 years. Drivers, supervisors, and general manual workers from company III also showed increased mortality from aortic aneurysm. One company, (II), showed raised mortality from other peripheral vascular disease (ICD—9th revision 443 O = 14, E = 8·8, SMR = 159, 95% CI 87–267).

CAUSES OF DEATH FROM MALIGNANT DISEASES

Table 9 gives the observed and expected deaths, the SMRs, and the 95% CIs for causes of death from malignancy for the total distribution centre study population, separately for the first and second, and the total follow up periods.

The mortality from all neoplasms was clearly low in the first follow up period but the observed deaths were only slightly less than those expected in the

| *30–39* | | | | *40–49* | | | | *⩾50* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* |
| 2074 | 2229·5 | 93 | (89–97) | 1743 | 1868·7 | 93 | (89–98) | 1758 | 1890·2 | 93 | (89–97) |
| 567 | 608·9 | 92 | (84–101) | 441 | 479·0 | 92 | (84–101) | 388 | 418·2 | 93 | (84–102) |
| 50 | 63·8 | 78 | (58–103) | 55 | 51·6 | 107 | (80–139) | 29 | 40·6 | 71 | (48–103) |
| 50 | 38·6 | 130 | (96–171) | 27 | 31·0 | 87 | (57–127) | 32 | 30·0 | 107 | (73–151) |
| 26 | 27·7 | 94 | (61–137) | 23 | 22·5 | 102 | (64–153) | 24 | 20·3 | 118 | (76–176) |
| 5 | 6·2 | 81 | (26–189) | 4 | 4·7 | 85 | (23–217) | 7 | 3·7 | 191 | (77–393) |
| 217 | 248·4 | 87 | (76–100) | 178 | 196·2 | 91 | (78–105) | 118 | 149·3 | 79 | (65–95) |
| 37 | 34·3 | 108 | (76–149) | 36 | 33·0 | 109 | (76–151) | 54 | 47·2 | 115 | (86–150) |
| 20 | 11·1 | 180 | (110–279) | 10 | 7·6 | 132 | (63–243) | 6 | 5·7 | 105 | (38–228) |
| 16 | 12·4 | 129 | (74–209) | 12 | 9·5 | 127 | (65–221) | 7 | 9·2 | 76 | (31–157) |
| 167 | 197·7 | 84 | (72–98) | 192 | 190·1 | 101 | (87–116) | 243 | 221·7 | 110 | (96–124) |
| 774 | 728·8 | 106 | (99–114) | 594 | 592·2 | 100 | (92–109) | 524 | 546·3 | 96 | (88–105) |
| 58 | 50·0 | 116 | (88–150) | 57 | 49·8 | 115 | (87–148) | 70 | 66·0 | 106 | (83–134) |
| 77 | 84·8 | 91 | (72–114) | 81 | 93·8 | 86 | (69–107) | 127 | 151·1 | 84 | (70–100) |
| 93 | 129·3 | 72 | (58–88) | 108 | 130·5 | 83 | (68–100) | 74 | 110·2 | 67 | (53–84) |

*Table 8 Observed (O) and expected (E) deaths, SMRs, and 95% CIs for aortic aneurysm by company and other subgroups*

| *Subgroup* | *O* | *E* | *SMR* | *(95% CI)* |
|---|---|---|---|---|
| Company: | | | | |
| I | 12 | 8·1 | 149 | (77–260) |
| II | 67 | 72·2 | 93 | (72–118) |
| III | 54 | 37·0 | 146 | (110–191) |
| Total | 133 | 117·2 | 113 | (95–134) |
| Age: | | | | |
| <60 | 21 | 19·4 | 108 | (67–165) |
| 60–69 | 42 | 36·1 | 116 | (84–157) |
| 70–79 | 48 | 44·8 | 107 | (78–142) |
| ⩾80 | 22 | 16·9 | 130 | (82–197) |
| Job: | | | | |
| Driver from company III | 20 | 12·7 | 158 | (96–244) |
| Supervisor from company III | 10 | 4·9 | 203 | (97–373) |
| General manual worker from company III | 4 | 1·5 | 270 | (74–692) |

second period. This higher mortality in the second follow up period was reflected in many of the individual groups of neoplasms, for example, malignant neoplasms of the oesophagus, stomach, liver and gall bladder, pancreas, lung, and bladder. It was pronounced for malignant neoplasms of the intestines, and larynx. The SMRs were similar for the two follow up periods for leukaemia, melanoma, and malignant neoplasms of the prostate and kidneys, and lower in the second period for malignant neoplasms of the rectum and brain, lymphosarcoma, Hodgkin's disease, and multiple myeloma. There were a few SMRs greater than 100 for the total study population for the total follow up period—namely, malignant neoplasms of the larynx, prostate and kidney, Hodgkin's disease, and leukaemia—but none of these were raised appreciably (as judged by the confidence interval).

*Malignant neoplasms of the digestive tract*

With the exception of malignant neoplasm of the rectum the mortality from diseases in this group tended to increase in the second follow up period, appreciably so for malignant neoplasm of the intestines. The only raised mortality found was in this last group, in clerical, administrative, and clerical workers (O = 34, E = 21·0, SMR = 162, 95% CI 112–226), particularly at company II (O = 25, E = 13·2, SMR = 189, 95% CI 123–280). There was a tendency for mortality from malignant neoplasms of the intestines to increase as time since first employment increased to 30-39 years (table 5).

*Malignant neoplasms of the respiratory system*

Mortality from malignant neoplasm of the larynx increased greatly in the second follow up period particularly at company I (O = 5, E = 1·7, SMR = 302, 95% CI 98–704) and, to a lesser extent, at company II (O = 20, E = 14·9, SMR = 134, 95% CI

*Table 9 Observed (O) and expected (E) deaths, SMRs, and 95% CIs for malignant causes of death*

| | *Follow up 1951–75* | | | | *Follow up 1976–89* | | | | *Follow up 1951–89* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Disease* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* | *O* | *E* | *SMR* | *(95% CI)* |
| All malignant neoplasms | 1012 | 1137·7 | 89 | (84–95) | 1304 | 1333·0 | 98 | (93–103) | 2316 | 2470·7 | 94 | (90–98) |
| Malignant neoplasms of the buccal cavity and pharynx | 14 | 17·0 | 82 | (45–138) | 11 | 19·6 | 56 | (28–100) | 25 | 36·6 | 68 | (44–101) |
| Oesophagus | 17 | 27·6 | 62 | (36–99) | 33 | 46·9 | 70 | (48–99) | 50 | 74·5 | 67 | (50–89) |
| Stomach | 124 | 142·2 | 87 | (73–104) | 114 | 115·3 | 99 | (82–119) | 238 | 257·5 | 92 | (81–105) |
| Intestine | 57 | 70·4 | 81 | (61–105) | 103 | 89·7 | 115 | (94–139) | 160 | 160·1 | 100 | (85–117) |
| Rectum | 56 | 52·7 | 106 | (80–138) | 49 | 61·0 | 80 | (59–106) | 105 | 113·7 | 92 | (76–112) |
| Liver and gall bladder | 15 | 20·2 | 74 | (42–122) | 17 | 20·5 | 83 | (48–133) | 32 | 40·7 | 79 | (54–111) |
| Pancreas | 38 | 46·0 | 83 | (58–113) | 60 | 56·9 | 105 | (80–136) | 98 | 102·9 | 95 | (77–116) |
| Larynx | 10 | 11·5 | 87 | (42–160) | 23 | 12·5 | 184 | (117–276) | 33 | 24·0 | 138 | (95–193) |
| Lung and pleura | 391 | 476·0 | 82 | (74–91) | 482 | 501·4 | 96 | (88–105) | 873 | 977·4 | 89 | (83–95) |
| Melanoma | 3 | 4·9 | 61 | (13–179) | 5 | 7·5 | 67 | (22–156) | 8 | 12·4 | 65 | (28–127) |
| Prostate | 54 | 47·1 | 115 | (86–150) | 112 | 101·5 | 110 | (91–133) | 166 | 148·6 | 112 | (95–130) |
| Bladder | 33 | 41·9 | 79 | (54–111) | 51 | 55·5 | 92 | (68–121) | 84 | 97·4 | 86 | (69–107) |
| Kidney | 23 | 18·6 | 124 | (78–186) | 30 | 25·2 | 119 | (80–170) | 53 | 43·8 | 121 | (91–158) |
| Brain | 39 | 36·1 | 108 | (77–148) | 26 | 28·0 | 93 | (61–136) | 65 | 64·1 | 101 | (78–129) |
| Reticulum cell sarcoma | 2 | 6·4 | 31 | (4–113) | 1 | 1·2 | 83 | (2–464) | 3 | 7·6 | 40 | (8–116) |
| Lymphosarcoma | 7 | 6·8 | 103 | (41–212) | 2 | 3·5 | 57 | (7–206) | 9 | 10·3 | 88 | (40–167) |
| Hodgkin's disease | 17 | 12·1 | 141 | (82–225) | 2 | 4·8 | 42 | (5–151) | 19 | 16·9 | 113 | (68–176) |
| Other neoplasms of lymphoid tissue | 6 | 3·5 | 171 | (63–373) | 18 | 20·3 | 89 | (53–140) | 24 | 23·8 | 101 | (65–150) |
| Multiple myeloma | 11 | 9·2 | 120 | (60–214) | 13 | 17·0 | 76 | (41–131) | 24 | 26·2 | 92 | (59–136) |
| Leukaemia | 28 | 26·4 | 106 | (70–153) | 33 | 30·0 | 110 | (76–154) | 61 | 56·4 | 108 | (83–140) |

82–208). Several job groups—namely, operators (O = 7, E = 4·95, SMR = 141, 95% CI 57–292), drivers (O = 14, E = 9·3, SMR = 150, 95% CI 82–252), and craftsmen (O = 4, E = 1·54, SMR = 259, 95% CI 71–663)—showed slightly increased mortality from this disease. There was a tendency for mortality from malignant neoplasm of the larynx to increase with increasing year of entry with a corresponding decrease with time since first employment (table 5). Whereas mortality from malignant neoplasm of the lung was still lower than expected in the second follow up period the trend was for increasing mortality from this disease as the calendar period of follow up increased. Mortality was slightly increased for operators and general manual workers.

*Melanoma and other skin neoplasms*

Unlike the refinery study there were no raised mortality patterns from melanoma or other skin neoplasms.

*Malignant neoplasms of the genitourinary system*

Mortality was raised overall for both follow up periods for malignant neoplasms of the prostate and kidney, and increased in the second follow up period, although it was still lower than expected for malignant neoplasm of the bladder.

Mortality from malignant neoplasm of the prostate was raised only in company II (O = 113, E = 89·6, SMR = 126, 95% CI 104–152), particularly in operators (O = 29, E = 17·7, SMR = 164, 95% CI 110–235), and to a lesser extent in security men (O = 8, E = 4·6, SMR = 174, 95% CI 75–343). Mortality from this disease tended to increase as the time since first employment increased (table 5).

Although overall mortality from malignant neoplasm of the bladder was low mortality from this disease was clearly raised at company I, based on 12 observed deaths (E = 6·5, SMR = 185, 95% CI 96–324).

Details of the results for kidney cancer have been reported elsewhere.[3] Briefly, mortality from malignant neoplasm of the kidney was raised overall (O = 53, E = 43·8, SMR = 121, 95% CI 91–158) and in drivers in particular (O = 25, E = 17·7, SMR = 141, 95% CI 91–209). Mortality tended to decline as the year of entry increased with a corresponding increase with the time since first employment up to 30-39 years (table 5).

*Malignant neoplasm of the brain and central nervous system*

The mortality from this disease group was slightly lower in the second follow up period than in the first, giving an SMR for the total follow up period of 101 (see table 9). As in the refinery study there was no evidence of raised mortality for this disease group.

*Malignant neoplasms of lymphatic and haematopoietic tissue*

In general the numbers of observed deaths in these disease groups were small, making interpretation of the results difficult. There was little evidence of raised mortality in three of the groups, namely reticulum cell sarcoma, Hodgkin's disease, and multiple myeloma.

There was only one excess of observed deaths compared with those expected in lymphosarcoma —namely, in general manual workers but it was based on only three observed deaths (E = 0·72, SMR = 418, 95% CI 86–1223).

Mortality from other neoplasms of the lymphoid tissue was lower in the second follow up period than in the first. There was a pronounced excess of observed deaths from this disease in operators based on 10 observed deaths (E = 5·03, SMR = 199, 95% CI 95–365).

The results for leukaemia have been reported in detail elsewhere.[3] Mortality was similar in both follow up periods and tended to increase with increasing time since first employment (table 5). There was no clear pattern by year of entry. No one type of leukaemia showed appreciably increased mortality.

Nearly 75% of the deaths from leukaemia occurred in company II (O = 46, E = 35·5, SMR = 130, 95% CI 95–173) and raised mortality was found in this company for lymphatic leukaemia, particularly chronic lymphatic leukaemia (O = 15, E = 8·52, SMR = 176, 95% CI 99–290), and to a lesser extent acute myeloid leukaemia (O = 17, E = 13·15, SMR = 129, 95% CI 75–207). Mortality was raised in drivers (O = 28, E = 22·4, SMR = 125, 95% CI 83–181), mostly at company II (O = 21, E = 14·6, SMR = 133, 95% CI 89–220). Nineteen of the deaths from leukaemia in drivers were from myeloid leukaemia (E = 8·34, SMR = 156, 95% CI 83–267) and thirteen were from acute myeloid leukaemia (E = 8·39, SMR = 155, 95% CI 82–265).

## Discussion

The limitations of this type of mortality study and the problems inherent in the interpretation of the results have been discussed elsewhere.[4]

Differences in the mortality patterns between the three companies may be due to differences in the workforce or type of distribution centres. Details have been discussed previously[1 2] but the distribution centres (about 750) covered in the study period varied in age, numbers of men eligible for the study (between one and 800), and type (six were lubricating oil blending plants, and 22 were

airports). About 4% of both the study population and of those dead were men employed at blending plants. Men employed at airports accounted for 8% of the study population but only 3% of the deaths. The numbers were thus too small for separate analysis. An examination of the deaths by distribution centre, however, did not show any obvious excesses of deaths at any individual or type of centre.

As discussed earlier the information from company III was taken mainly from pension records (71% of those who left company III were retirees compared with 14% and 33% from companies I and II respectively), and records for men leaving for reasons other than death or retirement were mostly unavailable. An appreciable number of men from company III were therefore not included in the study. Those omitted were likely to have been younger and with shorter service and might thus have contributed fewer deaths to the study than men who retired. Company I had a larger number who left for reasons other than death or retirement. These men were generally young when they left and duration of service was short.

Dates of leaving for those in post at 31 December 1975 were not obtained from the companies for the second follow up. An analysis by duration of service was therefore not possible. No information was collected on job history either within or outside the oil industry for the same reasons outlined in the refinery study paper.[4] Data on exposures to potential hazards were also not available and neither was information on lifestyle, such as smoking habits, alcohol consumption, diet, or leisure activities.

As in the refinery study the number of deaths have more than doubled, from 3903 in the first follow up to 8743 at 31 December 1989, and the person-years have increased by around 230 000. The overall relative mortality of the study population remained low, a continuation of the healthy worker effect.

This lowered mortality was also reflected in many of the numerically large non-malignant causes of death such as cerebrovascular disease, diseases of the arteries, pneumonia, and bronchitis. Some of the individual job groups showed slightly raised mortality from specific non-malignant disease, in particular stroke and heart disease in general manual workers. Similar to the refinery study the expected deaths were not adjusted to take into account variations in mortality by social class. Many of the diseases for which increased mortality was found in general manual workers, show appreciable trends from low to high mortality for social classes I to V. If adjustment had been made to the expected number of deaths for general manual workers with the data for social class V the increased mortality would have been greatly diminished or would have disappeared altogether. In a similar manner low mortality was found for craftsmen, supervisors, and clerical, administration and managerial staff. Mortality was increased in security men for some non-malignant diseases, in particular bronchitis, but there was a tendency for men who developed poor health to be transferred from other work to this job.

The consistently raised mortality from ischaemic heart disease is more difficult to interpret, because it is raised across several job groups and age groups. The patterns for this disease were by contrast with those of most of the heart disease groups, in which the mortality was generally low, and also at variance with many other occupational studies. Increased mortality was also found for diseases of the arteries, in particular, aortic aneurysm, although to a lesser extent than in the refinery study.

Mortality from all neoplasms was once again lower than expected, due mainly to considerable deficits in mortality from malignant neoplasm of the lung. This mortality tends to increase, however, as the follow up period increases, with increased mortality for general manual workers. There are no data on the smoking habits of distribution centre workers but it may be that their smoking habits are different from those of the general population. There was also a tendency for mortality from malignant neoplasm of the larynx to increase as the calendar period of follow up increased, with increased mortality from this disease being found in several job groups.

Unlike the refinery study there was no increased mortality for malignant neoplasms of the digestive tract, although an isolated excess of observed deaths from malignant neoplasm of the intestines occurred in clerical, administrative, and managerial staff. Again there was no raised mortality from melanoma.

The drivers and operators are probably the two groups with most exposure to any potential chemical hazard, in particular hydrocarbons. Concern has been expressed about raised mortality from such diseases as malignant diseases of the prostate, kidney, and brain, leukaemia, and other lymphatic neoplasms.[7 26-29] Neurological disorders have also been suggested as being exacerbated by exposure to petroleum hydrocarbons.[20 22] As discussed, however, no data on exposures to hydrocarbons were collected in this study.

As in the refinery study, the slightly raised mortality from malignant neoplasm of the prostate continued in the second follow up period, with operators again having the most pronounced increases in mortality. Mortality from malignant neoplasm of the kidney was raised overall and in

drivers in particular. There was a tendency for the mortality to increase with increasing time since first employment.

As in the refinery study there was no raised mortality from malignant neoplasm of the brain.

Particular interest has been shown in mortality from leukaemia and its possible relation with exposure to benzene and other solvents.[30-32] The total observed deaths from leukaemia were once again slightly higher than those expected, but substantially increased in only one company. Nearly half of the deaths from leukaemia occurred in drivers, and mortality was raised for drivers for myeloid leukaemias, and in particular acute myeloid leukaemia.

In conclusion, the mortality of the distribution centre study population has continued to be lower than that of the general population, both overall and from many of the numerically large disease groups. The lack of a healthy worker effect in ischaemic heart disease has continued and there are some other specific raised mortality patterns that may warrant further investigation. As in the refinery population, the population of the distribution centres is now largely flagged at the NHSCRs and as further deaths occur in the cohort the death certificates will be provided. Future patterns of mortality could thus be monitored routinely. Specific issues of particular concern—for example, the raised mortality from aortic aneurysm and, as suggested elsewhere,[3] kidney cancer and leukaemia—could be further investigated by carrying out nested case-control studies.

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1 Rushton L, Alderson MR. An epidemiological survey of oil distribution centres in Great Britain. *Br J Ind Med* 1983; **40**:330–9.
2 Rushton L, Alderson MR. *An epidemiological survey of oil distribution centres in Great Britain—final report.* London: Institute of Petroleum, 1982.
3 Rushton L. A 39 year follow up of the UK oil refinery and distribution centre studies: results for kidney cancer and leukaemia. *Environ Health Perspect* 1993 (in press).
4 Rushton L. Further follow up of mortality in a United Kingdom oil refinery cohort. *Br J Ind Med* 1993;**50**:549–60.
5 Hanis NM, Stavraky KM, Fowler JL. Cancer mortality in oil refinery workers. *J Occup Med* 1979;**21**:167–74.
6 Christie D. The Australian petroleum industry health surveillance programme, seventh annual report 1987. *Health Watch* 1987.
7 Christie D. *Health Watch. The Australian petroleum industry health surveillance programme. Eighth report 1988-89.* Melbourne: Department of Community Medicine, University of Melbourne, 1990;1–75.
8 Harrington JM. Health experience of workers in the petroleum manufacturing and distribution industry: A review of the literature. *Am J Ind Med* 1987;**12**:475–97.
9 Goldstein DH, Benoit JN, Tyroler HA. An epidemiologic study of an oil mist exposure. *Arch Environ Health* 1970; **21**:600–3.
10 Pasternack B, Ehrlich L. Occupational exposure to an oil mist atmosphere—A twelve year mortality study. *Arch Environ Health* 1972;**25**:286–94.
11 Decoufle P. Further analysis of cancer mortality patterns among workers exposed to cutting oil mists. *J Natl Cancer Inst* 1978;**61**:1025–30.
12 Moss E, Scott TS, Atherley GRC. Mortality of newspaper workers from lung cancer and bronchitis 1952-1956. *Br J Ind Med* 1972;**29**:1–14.
13 Ask-Upmark E. Bronchial carcinoma in printing workers. *Dis Chest* 1955;**27**:427–35.
14 Ronneberg A, Andersen A, Skyberg K. Mortality and incidence of cancer among oil exposed workers in a Norwegian cable manufacturing company Part 2 Mortality and cancer incidence 1953-84. *Br J Ind Med* 1988;**45**:595–601.
15 Irving WS, Grumbles TG. Benzene exposures during gasoline loading at bulk marketing terminals. *Am Ind Hyg Assoc J* 1979;**40**:468–73.
16 Phillips CF, Jones RK. Gasoline vapour exposure during bulk handling operations. *Am Ind Hyg Assoc J* 1978;**39**:118–28.
17 Parkinson GS. Benzene in motor gasoline—An investigation into possible health hazards in and around filling stations and in normal transport operations. *Ann Occup Hyg* 1971; **14**:155–7.
18 McDermott HJ, Vos GA. Service station attendants' exposure to benzene and gasoline vapours. *Am Ind Hyg Assoc J* 1979; **40**:315–21.
19 Page NP, Mehlman M. Health effects of gasoline refuelling vapours and measured exposures at service stations. *Toxicol Ind Health* 1989;**5**:869–90.
20 Schwartz E. Proportionate mortality ratio analysis of automobile mechanics and gasoline service station workers in New Hampshire. *Am J Ind Med* 1987;**12**:91–9.
21 de Silva PE. Petrol vendors, capillary blood lead levels and contamination. *Med J Aust* 1977;**1**:344–7.
22 Knave B, Olsen BA, Elofsson S, *et al.* Long-term exposure to jet fuel. II A cross-sectional epidemiologic investigation on occupationally exposed industrial workers with special reference to the nervous system. *Scand J Work Environ Health* 1978;**4**:19–45.
23 Schenker MB. Diesel exhaust—An occupational carcinogen? *J Occup Med* 1980;**22**:41–6.
24 Waller RE. Trends in lung cancer in London in relation to exposure to diesel fumes. In: *Proceedings of meeting on health effects of diesel exhaust.* Washington, DC: EPA, 1979.
25 Wong O, Morgan RW, Kheifets L, Larson SR, Whorton MD. Mortality among members of a heavy construction equipment operators union with potential exposure to diesel exhaust emissions. *Br J Ind Med* 1985;**42**:425–48.
26 Phillips SC. A review of human kidney effects of hydrocarbon exposure. In: *Proceedings of a workshop on kidney cancer effects of hydrocarbons.* Washington DC: American Petroleum Institute, 1983.
27 Enterline PE, Viren J. Epidemiologic evidence for an association between gasoline and kidney cancer. *Environ Health Perspect* 1985;**62**:303–12.
28 Reeve GR, Bond GG, Lloyd JW, Cook RR, Waxweiler RJ, Fishbeck WA. An investigation of brain tumours among chemical plant employees using a sample-based cohort method. *J Occup Med* 1983;**25**:387–93.
29 Thomas TL, Stewart PA, Stemhagen A, *et al.* Risk of astrocytic brain tumours associated with occupational chemical exposures. *Scand J Work Environ Health* 1987;**13**:417–23.
30 Austin H, Delzell E, Cole P. Benzene and leukaemia—A review of the literature and a risk assessment. *Am J Epidemiol* 1988;**127**:419–39.
31 Rinsky RA, Young RJ, Smith AB. Leukaemia in benzene workers. *Am J Ind Med* 1981;**2**:217–45.
32 Swaen GMH, Meijers JMM. Risk assessment of leukaemia and occupational exposure to benzene. *Br J Ind Med* 1989; **46**:826–30.

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