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Mortality of tar distillation workers

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MACLAREN WM, HURLEY JF. Mortality of tar distillation workers. *Scand J Work Environ Health* 13 (1987) 404–411. Two hundred and fifty-five British tar distillery workers were followed from 1 January 1967 to 31 December 1983. Seventy-five men had died by the end of the follow-up, compared with 73.3 deaths expected on the basis of age-specific regional population death rates. Excess mortality occurred from lung cancer (12 deaths, 7.5 expected), bladder cancer (3 deaths, 0.7 expected) and diseases of the arteries and veins (5 deaths, 2.1 expected). Although the number of deaths from ischemic heart disease was not significantly increased overall (29 deaths, 25.3 expected), eight deaths from this cause occurred among men under 55 years of age compared with 3.9 expected. Four small matched case-referent studies, comparing men who died from these four causes with survivors, failed to reveal any associations between excess mortality and job type. In the light of other studies, it is concluded that the excess lung and bladder cancer mortality was work-related, while the deaths from ischemic heart disease and diseases of the arteries and veins merit further investigation.

Key terms: bladder cancer, ischemic heart disease, lung cancer, occupation.

Following reports of increased death rates from lung cancer among American coke workers (12), two studies of mortality were begun among British coke workers employed by the British Steel Corporation (BSC) and National Smokeless Fuels Limited (NSF Ltd). Attached to two of the 13 NSF coke works involved in these studies were two tar distillation plants* operated by a distinct but associated company. Because of the differences in work environment between the tar distillation plants and the coke works, it was decided to carry out a separate study of the mortality among the tar workers, and the results of this study form the subject of the present paper. Workers from two other tar distillation plants, not attached to any coke works, were subsequently added to the study group. Thus the total number of plants was four.

Previous studies of workers exposed to coal tar and pitch (the residue of tar distillation) had shown that mortality from several causes might be expected to be relatively high among tar distillation workers. Thus Henry et al (8) found an excess of bladder cancer deaths in a group of 2 665 such workers, while Hammond et al (7), in a study of 5 939 American roofers, reported an increasing standardized mortality ratio for lung cancer with increasing time since the workers joined the roofers' union. Other causes of death of prior interest were identified in studies of workers in the related coal gasification and coke production industries, where it seemed plausible that workers would be exposed to some of the gases and

agents encountered in tar distillation. For example, in studies of British gas workers, Doll et al (4, 5) found excess mortality from bronchitis (but only in the first study), as well as from lung cancer and bladder cancer, and Hurley et al (9) reported significant excess mortality from ischemic heart disease in a subgroup of comparatively young British coke workers (aged less than 45 years at death). Studies of workers exposed to coal tars in many different industrial settings have been recently discussed (10, 11).

The present study had the following two objectives: (i) to compare death rates in a group of British tar distillation workers over a 17-year period from 1967 to 1983 with those of the general regional populations of England and Wales and (ii) by comparing the occupational histories of men who died with those of survivors, to identify possible links between job type and any excess mortality shown in the first part of the study.

Subjects and methods

Study group definition

The group comprised all male manual workers employed on 1 January 1967 at four tar distillation plants. Two of these plants (code numbers 15 and 16) were distinct self-contained units. The other two (code numbers 2 and 10) were each attached to one of 13 coke works operated by NSF Ltd. Plants 2 and 16 were situated in the northern region of England and Wales, plant 10 in the east midlands, and plant 15 in south Wales.

Study group identification and data acquisition

During 1972–1973 clerical staff at 13 NSF coke works were asked to identify men who had been employed

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at their establishments on 1 January 1967. Men employed at tar plants 2 and 10 were included in this identification procedure and were later distinguished from their NSF colleagues on the basis of job and place of work. Men at plants 15 and 16 were included in the data collection program at a later stage.

In addition to identification information for these men (name, national insurance number, date of birth, last known address), an occupational history was obtained, comprising details of all jobs done within the coke works or tar distillation plant, as appropriate. Histories were gathered in the first place from company records and were supplemented with information obtained in interviews with current employees or with former employees living locally or with colleagues of former employees (9).

Note that men employed by NSF on 1 January 1967 did not satisfy the study definition and were not included in the study group. However, there were two groups of NSF workers who were liable to tar exposure and so were of particular interest. One such group consisted of men employed at the tar distillation plants before 1 January 1967. The second group was that of maintenance men at the NSF coke works associated with tar plant 2, whose duties included maintenance of the attached tar distillation plant. Fuller results on the mortality of both groups will be reported as part of the continuing study of coke workers in Britain.

Vital status

Arrangements were made with the Office of Population Censuses and Surveys (OPCS) for England and Wales to follow-up all those included in the study group, using the facilities of the National Health Service Central Register. Vital status on 31 December 1983 was determined solely on the basis of information from the Register. Notification of death was accompanied by a copy of the death certificate, coded according to the International Statistical Classification of Disease, Injuries and Causes of Death (ICD). The eighth revision of the ICD coding was used for deaths from 1968 onwards. Only the primary cause of death was used in the mortality analyses.

Study group description and follow-up

Two hundred and fifty-nine men were identified as eligible for the study. By June 1984, the vital status of 256 (98 %) of them had been confirmed by OPCS. Of the three men of unknown status, two could not be traced and one had emigrated. Another man had been reported, by clerical staff at the plant where he worked, as having died in 1969, but a copy of the death certificate had not been received from OPCS by June 1984. These four men were excluded from subsequent analyses of mortality, leaving a study group of 255 traced men.

When the statistical analyses were almost complete, it was discovered that a surviving member of the group

Table 1. Joint frequency distribution of age at 1 January 1967 and time elapsed since joining the tar plants at 1 January 1967 for the 255 traced men. (The frequency distribution for the four excluded men is given in parentheses.)

Age (years)	Time elapsed since joining the tar plants (years)					All times
	≤ 9	10–19	20–29	30–39	≥ 40	
15–24	8	—	—	—	—	8
25–34	34 (1)	5	—	—	—	39 (1)
35–44	44	20	3	—	—	67
45–54	30	23 (2)	16	3	—	72 (2)
55–64	25	12	15	9 (1)	8	69 (1)
All ages	141 (1)	60 (2)	34	12 (1)	8	255 (4)

of 255 men had been working as an electrician at a coal carbonization plant on 1 January 1967 and had not joined a tar plant until 1973. He remained in the analysis.

Table 1 shows the joint distribution of age at 1 January 1967 and the time elapsed between the date of first joining the tar plants and 1 January 1967 for the 255 traced men. The average age and time elapsed were 46 years and 12 years, respectively; 55 % of the men were over 45 years of age; for 45 % of them at least 10 years had elapsed since they had joined the plants.

Classification of occupational history

The occupational history recorded for each man in the study group included the names of all jobs done since joining the tar plants up to 1975–1976, the corresponding locations within the plant, and the starting and finishing dates for each job. Every combination of job name and place of work occurring in the histories was subsequently assigned to one of five categories as follows. Any job involving full-time work with pitch was assigned to category 1. Category 2 included all jobs requiring full-time work either on the tar distillation process or in dealing with products of the distillation process. Jobs demanding less than full-time work on tar distillation or with products were placed in category 3. These were mostly labor jobs for which the exact place of work was not known. Maintenance jobs (eg, electrician, fitter, carpenter) were assigned to category 4, and the fifth and final category consisted of other jobs, carried out in a variety of locations and not connected directly with the tar distillation process.

Statistical methods — External comparisons of mortality

The statistical analysis was carried out with the "person-years-at-risk" method (1) as follows. In each year of the follow-up period, the total number of years lived by the members of the study group (including fractions of years for those men who died) was allocated to cells defined jointly by plant, 10-year age group, and 10-year interval measuring time elapsed since joining the industry. The calculation allowed for

the possibility of a subject contributing to more than one cell during a calendar year, depending on his date of birth and date of joining the tar plants. Observed numbers of deaths were similarly allocated. Expected numbers of deaths from each cause considered were calculated by multiplying observation time by general population death rates specific to calendar year, 10-year age group, and geographic region. The results are presented as tables of observed and expected numbers of deaths by various combinations of the classifying variables, together with standardized mortality ratios, ie, the ratio of observed to expected numbers. The statistical significance of the standardized mortality ratio (SMR) values was assessed on the assumption that observed numbers followed the Poisson distribution, with means equal to expected numbers. Score tests (1) were used to assess the significance of differences between the SMR values across, for example, plants in the study.

In the analyses, several causes of death were examined, chosen partly on the basis of a possible work-related hazard, but also with knowledge of the various causes from which men in the study group had died up to December 1983. All the cause groups were defined in terms of both the eighth and ninth revisions of the ICD. Death rates for 1968 were used to estimate those of 1967, and so definition in terms of the seventh ICD revision was not necessary. In addition, rates for 1983 were estimated from the 1982 rates since, at the time of the analysis, the 1983 rates had not been published. Regional death rates were obtained from the Registrar General's annual statistical reviews for the period prior to 1974, and from OPCS publications for 1974 and subsequent years.

Table 2. Observed (O) and expected^a (E) deaths over 17 years from 1967 to 1983, inclusive, among the 255 traced men.^b (SMR = standardized mortality ratio)

Cause of death ^c	O	E	SMR
Malignant neoplasms (140-209)	19	18.2	104
Trachea, bronchus and lung (162)	12	7.5	160
Bladder (188)	3	0.7	429
Malignant melanoma (172)	1	0.1	.
Other malignant neoplasms	3	9.9	30
Diseases of the circulatory system (390-458)	45	37.9	119
Ischemic heart disease (410-414)	29	25.3	114
Cerebrovascular disease (430-438)	7	6.8	103
Diseases of arteries, arterioles and capillaries; diseases of veins and lymphatics; and other diseases of the circulatory system (440-458)	5	2.1	242
Other diseases of the circulatory system	4	3.7	108
Pneumonia (480-486)	3	3.4	87
Bronchitis, emphysema and asthma (490-493)	2	4.8	.
Other causes	6	9.0	67
All causes	75	73.3	102

^a Expected numbers of deaths were calculated with the use of regional rates for all of the tabulated causes except malignant melanoma. For this cause, rates for England and Wales were used. Regional rates for bladder cancer became available in 1979; expected numbers of deaths from this cause for the period 1967-1978 were calculated with the use of rates for England and Wales.

^b Total person-years 3 765.

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

Statistical methods — Mortality and occupation

A detailed investigation of possible connections between job type and subsequent mortality was undertaken with the case-referent methods as follows. Men who had died (cases) from one of a selected number of causes of death were compared with men from the same plant who had survived to December 1983 (referents), matched on date of birth and date of joining the tar plants to within five years but otherwise randomly chosen. When there were no survivors satisfying these conditions, the requirement of matching to within five years was relaxed in a systematic way until the appropriate number of referents was obtained. The cases and referents were compared in respect of time worked in the five job categories from the date of joining the tar plants to the date of the death of the case or to when the occupational histories of the cases and referents were recorded (taken as February 1976), whichever occurred sooner.

Results

Comparison of mortality with that expected on the basis of regional death rates

The number of deaths observed, by cause, is shown in table 2 together with the numbers expected on the basis of regional death rates. The overall mortality was slightly greater than expected, with 75 deaths observed compared with 73.3 expected. Similarly, the 19 deaths from malignant neoplasms just exceeded the 18.2 expected. Among the neoplasms, notable excesses were from lung cancer (12 observed, 7.5 expected, $P = 0.08$) and bladder cancer (3 observed, 0.7 expected, $P = 0.03$). The single death from malignant melanoma occurred relative to 0.1 expected. Deaths from other cancers considered as a group were lower than expected (3 observed, 9.9 expected). Mortality from diseases of the circulatory system exceeded that expected, but the excess was not statistically significant ($P = 0.14$). The causes contributing to this observed excess were ischemic heart disease (29 observed, 25.3 expected, $P = 0.26$) and diseases of the arteries and veins (5 observed, 2.1 expected, $P = 0.06$). (The complete wording on the certificates for these five deaths is given in the appendix.) There was no excess mortality from pneumonia or from bronchitis, emphysema, and asthma.

In three age categories, the observed and expected numbers of deaths from all causes were roughly equal (table 3). The deaths from lung cancer all occurred in men over 55 years of age (12 observed, 6.6 expected, $P = 0.04$), and the three bladder cancer deaths (not shown in table 3) occurred in men over 65 years of age. Although the excess mortality from ischemic heart disease was not statistically significant overall, the eight deaths among men under 55 years of age occurred relative to 3.9 expected ($P = 0.04$).

Table 3. Observed (O) and expected (E) deaths among the 255 traced men by age at death for three cause groups.^a (SMR = standardized mortality ratio)

Cause of death	Age at death (years)								
	≤ 54			55–64			≥ 65		
	O	E	SMR	O	E	SMR	O	E	SMR
All causes	12	10.1	119	25	23.1	108	38	40.1	95
Malignant neoplasm of trachea, bronchus and lung	—	0.9	.	5	2.8	177	7	3.8	185
Ischemic heart disease	8	3.9	206	9	8.5	106	12	12.9	93

^a Person-years 2 036, 1 069, and 660 for the age ranges ≤ 54, 55–64, and ≥ 65, respectively.

Table 4. Observed (O) and expected (E) deaths among the 255 traced men by time elapsed at death since joining the tar plants, for three cause groups.^a (SMR = standardized mortality ratio)

Cause of death	Time elapsed since joining the tar plants (years)								
	≤ 19			20–39			≥ 40		
	O	E	SMR	O	E	SMR	O	E	SMR
All causes	34	28.8	118	26	32.1	81	15	12.5	120
Malignant neoplasm of trachea, bronchus and lung	3	3.0	99	6	3.3	180	3	1.2	259
Ischemic heart disease	17	10.1	169	10	11.3	89	2	4.0	.

^a Person-years 2 327, 1 211, and 227 for the time ranges ≤ 19, 20–39, and ≥ 40, respectively.

Table 5. Observed (O) and expected (E) deaths from ischemic heart disease among the 255 traced men by time elapsed at death since joining the tar plants and age at death. (SMR = standardized mortality ratio)

Time elapsed at death since joining the tar plants (years)	Age at death (years)											
	≤ 54				55–64				≥ 65			
	Person-years	O	E	SMR	Person-years	O	E	SMR	Person-years	O	E	SMR
≤ 19	1 658	7	2.9	245	472	4	3.6	110	197	6	3.8	158
20–39	378	1	1.0	.	532	4	4.3	94	301	5	5.9	85
≥ 40	—	—	—	.	65	1	0.5	.	162	1	3.4	.

There was no evidence of any real variation in the SMR for all causes of death with time elapsed since joining the tar plants ($0.2 < P < 0.3$) (table 4). The increasing trend in the SMR for lung cancer with time elapsed did not reach statistical significance ($P = 0.25$). Deaths from ischemic heart disease occurring among men with fewer than 20 years' service numbered 17 compared with 10.1 expected ($P = 0.03$).

The joint distribution of numbers of observed and expected deaths from ischemic heart disease by age and time elapsed since joining the tar plants is shown in table 5. There is a suggestion that the increased mortality already noted for men under 55 years of age may also have been present among the men aged 55 years or more, but having fewer than 20 years' work experience. However, with 10 deaths observed compared with 7.4 expected, this is not a statistically significant result ($P = 0.20$).

The plant-specific SMR values for all causes of death varied from 67 at plant 10 (11 deaths observed and 16.4

expected in a total of 60 men) to 148 at plant 2 (7 deaths observed and 4.7 expected in a total of 13 men), but in fact plant differences could have arisen by chance ($0.3 < P < 0.4$). Excess mortality from lung cancer was not plant-specific, but for ischemic heart disease there was an indication of excess at plant 15 (17 deaths observed and 11.8 expected in a total of 124 men). Of the eight deaths from this cause among men under 55 years of age, six were at plant 15 compared with 2.0 expected ($P = 0.02$).

Finally, there was no statistically significant evidence of real variation in the SMR values for mortality from all causes, lung cancer, or ischemic heart disease during the follow-up period.

Mortality in a group of maintenance workers

High proportional mortalities, compared with the group of 255 tar workers, occurred among 73 NSF

maintenance men, some of whom had worked in tar plant 2. In particular, 7 and 13 deaths, out of a total of 28, were caused by lung cancer and ischemic heart disease, respectively. The extent to which any excess mortality in this group is attributable to tar exposure is unknown.

Mortality and occupation

The cases selected for the case-referent analyses were confined to men who had died from lung cancer, bladder cancer, ischemic heart disease, and diseases of the arteries and veins. Because excess mortality from ischemic heart disease relative to a regional standard was found only among men under 55 years of age (table 3), cases for the analysis of this cause were restricted to men in this age group at death. The matching ratio between the cases and referents varied according to cause: twelve lung cancer cases and eight ischemic heart disease cases were each matched to two referents; five men who died from vein and artery disease to three referents, and two bladder cancer cases each to four referents. (One bladder cancer case had to be excluded because of poor information on his occupational history.) The process of random selection resulted in several men acting as referents in the analysis of more than one cause of death. Specifically, of a total of 49 referents, one man acted as referent in the analysis of three causes of death, 16 men in the analysis of two causes, and 32 men in the analysis of single causes of death.

A reasonably satisfactory age match was achieved, although the referents for bladder cancer and diseases of the arteries and veins tended to be younger on the average than their cases (8.8 and 6.1 years, respectively). Matching by time since joining the industry was satisfactory for the lung cancer, bladder cancer, and ischemic heart disease groups but rather less so for the diseases of arteries and veins group. Two of the men who died from this cause had worked so long in the industry that referents with equally long times could not be found. (The six men finally chosen as referents for these two cases had worked 18 fewer years on the average at the start of the follow-up.)

In general, the results from the case-referent studies were negative, only a single case-referent difference being statistically significant. Thus, none of the five men who died from diseases of the arteries and veins had spent any time in the "other jobs" category, while their matched referents had spent an average of 4.4 years in this group ($0.02 < P < 0.05$). In addition these cases had spent an average of 18.8 years working part-time on distillation and by-products, thrice the time of their referents on the average, although the difference could have arisen by chance ($0.1 < P < 0.15$). Overall, therefore, there was no convincing evidence that any particular job in the plants contributed more to mortality than any others.

Detailed results of the case-referent studies are available on request.²

Discussion

Mortality from all causes

Seventy-five deaths from all causes were observed in the study group. On the assumption that death rates among the general local male population had applied to these men, 73.3 deaths would have been expected. A very slight excess death rate in the study group has therefore been established, and, on the grounds that working populations are expected to be healthier than the general population (6), this result may be considered suggestive of a work-related hazard.

There was anecdotal evidence that some members of the study group who had formerly worked in the coal-mining industry had left that industry for reasons related to health and had joined the tar distillation plants because the job was less physically demanding. If this was the case, then the study group could not be considered as subject to the "healthy worker" selection effect in a straightforward way. Sixty-nine of the 255 traced men in the study group had prior experience of working in coal mines. At plant 15, the corresponding figure was 58 out of 123 men, or 47 %. Of the 69 men with coal-mining experience, 20 (29 %) had died by the end of the follow-up, while, of the 186 men without such experience, 55 (30 %) had died. At plant 15, the corresponding percentages were 31 % (18 out of 58) and 31 % (20 out of 65), respectively. Thus a simple comparison of proportions tends not to support the idea that the comparatively high all-cause mortality of the tar workers was due to the preferential selection of less healthy coal workers into the industry.

Lung cancer

The excess mortality due to lung cancer (12 deaths observed, 7.5 expected), although not statistically significant at the conventional level of 5 %, adds further weight to the of evidence connecting lung cancer with coal tar work. It is of course possible that the excess is attributable, at least in part, to smoking. However Doll (3) has suggested that the smoking habits of occupational or other social groups in developed countries are unlikely to account for lung cancer mortality differences of 50 % greater than the national average. According to this criterion, the present excess may therefore be judged as providing evidence, albeit rather marginal, for the presence of an occupational hazard. This conclusion is further strengthened by the fact that regional death rates were used in the analysis. By this means, some degree of similarity between comparison groups will have been achieved, not only

² Institute of Occupational Medicine Technical Memorandum TM/86/1.

in respect of smoking habit, but also of general air pollution and socioeconomic status.

Bladder cancer

The number of deaths due to bladder cancer was very small (3 observed, 0.7 expected), but the SMR was high, and a connection between bladder cancer and the related coal carbonization and coal gasification industries has been documented (2, 4, 5, 8). It seems likely therefore that the excess is occupationally related.

Ischemic heart disease

The excess number of deaths from ischemic heart disease (29 observed, 25.3 expected) was not statistically significant, but among men under 55 years of age (8 observed, 3.9 expected) a significance level of 4 % was attained. This finding is similar to that of Hurley et al (9), who found 18 deaths against 11.9 expected in a group of British coke workers under 45 years of age.

The results of the present study provide at least an indication (table 5) that the excess mortality from this cause is to be found among men with fewer years of work experience in the tar industry rather than purely in younger men. Such a pattern of excess mortality differs from the increasing trend in SMR with time since first exposure commonly observed for occupational cancer, and we have been unable to find a simple explanation for it. A fairly limited search of the recent literature on mortality in occupational groups identified only one other study (reasonably comparable in design to the present one) in which the relationship between the SMR for ischemic heart disease and age at death was reported. This was a study of 23 358 oil distribution center workers in Britain who were followed between 1950 and 1975 (15). The relevant results appear in table 4 of that paper and show patterns similar to those of the tar workers.

The plant with the clearest indication of excess mortality from this cause (plant 15: 17 deaths, 11.8 expected) was also the plant with easily the highest proportion of men having previous coal-mining experience. Although it is possible that the increased SMR might be due to high mortality in this group of perhaps relatively unhealthy ex-coal workers, comparisons of proportions suggest this is not the case. Of the 58 ex-coal workers, 7 (12 %) died from ischemic heart disease, whereas 10 (15 %) of the 65 men with no coal-mining experience died from this cause.

Because of the difficulties of interpreting the age-related pattern of excess, and also the lack of corroborative evidence from other studies, it seems premature to suggest that the results imply that an increased risk of ischemic heart disease is associated with tar distillation work. Rosenman (14) has stated that attempts to relate exposure to specific chemicals, gases, dusts, or fumes to subsequent change in incidence or

prevalence of coronary arteriosclerotic heart disease have been few in number. He provides a list of known or suspected hazards. The findings of both the present study and that of Hurley et al (9) suggest that future hygienic studies of tar distillation and coke oven environments with the aim of identifying such agents might be of value.

Diseases of the arteries and veins

Because of the unexpectedness of the result, and also the lack of statistical significance at conventional levels (5 deaths observed, 2.1 expected, $P = 0.06$), the possibility that the excess mortality was due to chance should be considered, especially since many different causes of death have been investigated in the study. The case-referent study yielded no definite information on a possible association with occupation. The differences in time worked for job categories 3 and 5 were suggestive of an influence of job type, but the poor matching between certain cases and referents makes interpretation difficult.

Other causes of death

Two of the deaths from cerebrovascular disease occurred in men under 45 years of age compared to 0.1 expected. There could be a connection with the finding for ischemic heart disease in younger men; however, over all age groups, there was no excess (7 deaths, 6.8 expected).

The single death from skin cancer was due to malignant melanoma. This man was born in 1918 and joined the tar plants in 1960. Until his death in 1976 he worked as a benzene refiner for six years, and as a shift foreman for the rest of the time. Before joining the industry, he worked on coke ovens at a coke plant, but for an unknown period.

Finally, there was no excess mortality either from bronchitis, emphysema, and asthma or from digestive cancer, both of which have previously been shown to be associated with coal carbonization work (4,13).

The case-referent studies

In considering the question of whether the observed excess mortality in the study group of tar distillation workers is a consequence of occupation, it has been necessary to rely entirely on the results of the external comparisons of mortality and their relation to results of previous studies. The matched case-referent studies failed to indicate which jobs, if any, were associated with increased risk. With such small numbers of men involved, it was perhaps unlikely that such associations would be shown. However the system of job classification may also have contributed to the uninformative results. Lloyd (12) has stated that occupationally related disease may be obscured if a study is limited to broad occupational groups. Given the small numbers of men, it may be that the job classification

scheme used in this study was too crude to identify any associations which may have existed.

It is possible that matching cases and referents on date of joining the tar plants, as well as date of birth, may have reduced the likelihood of finding significant case-referent differences. This would be the case if duration of exposure, rather than intensity, was the main determinant of adverse health effects. On the other hand, the matching strategy actually adopted (which implies matching on duration of employment, as well as on calendar period of employment) insures that cases and referents share a common experience of varying overall plant conditions and that what might be loosely termed their "general background exposures" are broadly similar. Any associations between high mortality and specific jobs found under these matching constraints would necessarily be more convincing, and this reasoning motivated the design of the case-referent study.

Mortality among maintenance workers

The high proportional mortality from lung cancer and ischemic heart disease found in a group of NSF maintenance workers, some of whom would have been exposed to tar, is consistent with the results found for the tar workers' study group, and it provides a further indication of a link with occupation. However it would be necessary to carry out both a detailed exploration of the occupational histories of these men to determine which of them were tar exposed and a comparative mortality analysis for this subgroup before any stronger conclusion could be based on the observed mortality.

In conclusion, we regard the observed excess mortality from lung cancer and bladder cancer as an instance of association between these diseases and tar distillation work, despite the smallness of the study, and the negative outcome of the case-referent analyses. The findings on ischemic heart disease and diseases of the arteries and veins provide pointers for further investigation, but at present should be regarded as suggestive only.

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APPENDIX

Certificates of death from diseases of arteries and veins

The wording on the death certificates of the five men who died from causes included under the category “diseases of the arteries, arterioles and capillaries, diseases of veins and lymphatics, and other diseases of the circulatory system” was as follows:

Cause of death

- Case a
 - 1a Bronchopneumonia
 - 1b General arterial sclerosis
 - 1c Pneumoconiosis
- Case b
 - 1 Ruptured dissecting aneurysm of the aorta
- Case c
 - 1 Ruptured atheromatous aneurysm right common iliac artery
- Case d
 - 1a Bronchopneumonia
 - 1b Extensive peripheral vascular disease
 - 2 Previous CVA affecting L side
- Case e
 - 1a Bronchopneumonia
 - 1b Gangrene R foot
 - 1c Chronic obstructive airways disease
 - 2 Myocardial infarction. Diabetes mellitus and reverse colostomy for diverticulitis