A mortality study of Danish stokers

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Abstract
This study was set up to investigate whether work as a stoker is associated with an increased risk of specific malignant neoplasms. For this purpose, a cohort of 2777 male stokers was followed up through a 10 year period with regard to cause specific mortality. Comparisons were made with another cohort of unskilled male workers in physically demanding jobs. The mortality of the stokers was significantly increased for lung cancer (standardised mortality ratio (SMR) 145, 95% confidence interval (95% CI) 110–186) and for multiple myeloma (SMR 388, 95% CI 106–994). Also, increases were seen for cancer of the urinary organs and cancer of the mouth and throat. The combustion products to which the stokers have been exposed comprise several carcinogenic agents including polycyclic aromatic hydrocarbons, benzene, arsenic, and radionuclides. It seems likely that the occupational exposure of stokers has contributed to their excess cancer mortality.

The work environment of stokers typically involves intensive exposure to heat radiation, coal dust, and coal combustion gases and particulates. Publications available on the morbidity of stokers are sparse. A search revealed only two papers, which both date back to the 1930s and 1940s. In these papers increased risks for cancer of the lung and bladder were reported.1,2 Other occupational groups—for example, gas and coke plant workers—may have been exposed to almost the same agents as stokers have. In 1984, the International Agency for Research on Cancer (IARC) reviewed the published work on possible carcinogenic hazards in the coal gasification and coke production industries. The contaminants found in the work atmosphere included polycyclic aromatic hydrocarbons (PAHs), aromatic and aliphatic amines and aldehydes, lead, cadmium, arsenic, chromium, nickel, and vanadium.3 With regard to adverse health effects, it was concluded in the IARC review that there is "... sufficient evidence that certain exposures in the coke-production industry are carcinogenic to humans, giving rise to lung cancer... There is limited evidence that such occupational exposures produce bladder cancer (p 93)." The finding of an increased mutagenic activity in the sputum of coke plant workers4 is consistent with the increased lung cancer mortality that has been found in this occupational group. As well as the cancer sites already mentioned, an increased risk of cancer of the nose and nasal sinuses was recorded in a recent study of workers at a modern coal gasification plant.5

Subsequent to inhalation, PAHs have been found in the blood and urine along with DNA-benzo-(a)pyrene adducts in peripheral lymphocytes and antibodies to these adducts in the serum of coke plant workers.6,8 Furthermore, an increased frequency of chromatid aberrations and of sister chromatid exchange (SCE) has been shown in peripheral lymphocytes of exposed workers.9,10 These findings indicate (1) that inhaled PAHs may reach almost any tissue via the blood stream, (2) that PAHs are excreted in the urine, and (3) that exposure to coal combustion effluents is associated with an increased risk of chromosomal damage in blood cells.

The aim of this study was to throw further light on the possible relation between inhalation exposure to combustion effluents and specific cancer sites. On the basis of the publications referred to above, malignant neoplasms of the mouth and throat, digestive organs, respiratory organs, urinary organs, and lymphatic and haematopoietic tissues were anticipated to be of particular interest.

Subjects and methods
The research design was that of a historical cohort study in which the exposed part of the cohort was compared with the unexposed part in terms of cause specific mortality throughout a 10 year follow up
period. Stokers constituted the exposed part of the study cohort. The control group—namely, the unexposed part of the study cohort—was made up of other specific groups of unskilled workers.

**IDENTIFICATION OF THE SUBJECTS**

The members of the study cohort were identified from the files of a nationwide census carried out in Denmark on 9 November 1970. Self-reported occupation, trade, industry, and employment on the day of the census were recorded for all Danish inhabitants more than 14 years old. These data were used to select the persons included in the study.

The study was comprised exclusively of unskilled male workers between 15 and 74 years old who were occupationally active on the day of the census.

The exposed group comprised every unskilled male worker recorded as stoker, boilerman, or boiler attendant with employment elsewhere than at sea or in the transportation services. (It was impossible to obtain separate data for stokers and boilermen/boiler attendants).

The unexposed control group comprised certain hand-picked occupational groups of unskilled male workers in service trades (38% of the total comparison group), agriculture and forestry (36%), and specific light industries (26%). The occupational groups for comparison were defined by 102 combinations of specific job code and occupational sector code—for example, industrial labourers employed in the telephone companies or cleaners in social institutions. Such code combinations represent available entries to the census files mentioned above. The occupational groups for comparison were selected in such a way that they could be assumed to be unexposed to combustion effluents of coal or oil and to resemble the group of stokers in terms of work related demands on physical strength and fitness, social class, and geographical distribution.

In total, 2777 stokers and 43,024 unexposed unskilled workers were included in the study.

**EXPOSURE**

The members of the exposed cohort were employed by heating plants to tend plant furnaces and supply them with fuel.

Stokers who tended coal fuelled furnaces worked in district heating plants, power stations, and central heating plants. Boilermen and boiler attendants, on the other hand, supervised and tended the huge boilers in district heating plants.

The occupational hazards that may affect the workers tending the furnaces depend largely on the fuel used and the type of furnace. Coal stoking involves an opening of the combustion chamber every time fuel is to be supplied—a situation in which large amounts of hot burning soot and combustion gases stream into the boiler room. Compared with the coal fuelled furnaces, tending the oil fuelled ones results in much less intensive exposure to particulates and gases. Oil fuelled furnaces are operated with mechanised or semimechanised feeding and the combustion chamber is only opened when the furnace is to be cleaned of soot. Before cleaning the fire must be extinguished for several hours to allow the furnace to cool down.

In Denmark the first heating plants were built in the 1930s. Around 1950 district and central heating plants were prevalent in almost all urbanised areas, and around 1960 most homes in cities and towns were supplied with heating from these plants.

The Danish district heating plants have always been fuelled by coal. For the smaller central heating plants the furnaces were all of the coal stoked type until 1953. That year the use of oil for heating purposes was permitted by the government and from 1953 until now oil stoked furnaces have gradually replaced most of the coal stoked ones. Around 1970 about half of the central heating plants were based on oil stoked furnaces (personal communication, head of the Chimney Sweeps’ Union). (During the period 1970–90, natural gas from the North Sea became an energy source of growing importance. Until now, however, natural gas has almost exclusively been used for small individual heating installations in one family houses.)

When a central heating plant had the old coal stoked furnace replaced by an oil feed one, the stoker(s) who had tended the old furnace received a short course on how to tend an oil feed furnace and by attending this the stoker(s) kept his (their) employment. Thus, as well as the heavy exposure to coal combustion products, some of the stokers had also been exposed to oil combustion products.

As described above, tending oil feed furnaces results in considerably less intensive exposure to particulates and gases than does tending coal stoked furnaces. Furthermore, oil feed furnaces have been in use from 1953 only.

In conclusion, the stokers were heavily exposed to particulates and gases from coal combustion. Some of the stokers had a minor additional exposure to oil combustion products. The boilermen and boiler attendants, on the other hand, were hardly occupationally exposed to combustion products.

**FOLLOW UP PROCEDURES**

The Danish National Bureau of Statistics has established an automatic record link between the 1970 census register, the Central Population Register, and the Death Certificate Register. (Publication Nos 37 (1979) and 41 (1985) from the Danish National Bureau of Statistics, both in Danish.) Accordingly, any population identified in the 1970 census records may be automatically followed up with regard to
cause specific mortality within the 10 year period after 9 November 1970.

The automatic record link system was used to trace the members of the cohort and to ascertain causes of death. The study subjects were traced until 9 November 1980 or until death or emigration before this date. Deceased subjects, emigrants, and those lost to follow up contributed person-years at risk until the day of death, day of emigration, or last day of notification in the Central Population Register respectively.

The stokers and the comparison group of unexposed unskilled workers contributed 26,030 and 407,780 person-years at risk respectively. For those who had died, the study used the notified underlying cause of death.

DATA ANALYSIS
Expected numbers of deaths among the stokers were calculated from age and period specific death rates of the comparison group and the number of person-years at risk accumulated by the stokers.

Also, the mortality of the stokers was compared with that of the occupationally active part of the 1970 census population. For practical reasons the last comparisons were restricted to main groups of diagnoses and to ages 20 to 64 inclusive.

For the statistical evaluation, observed numbers beyond 100 were assumed to follow a normal distribution (Yates' correction was used) and a test based confidence interval for the standardised mortality ratio (SMR) was calculated. For smaller numbers a Poisson distribution was assumed, and a confidence interval based on exact Poisson limits was calculated. The death rates of the comparison population were assumed not to be influenced by random variation.

Results
The overall SMR was 93. Increased mortalities were recorded for cancer and respiratory diseases, whereas significant deficits were noted for other natural deaths exclusive of circulatory diseases and for external causes of death (table 1). The increased cancer mortality was mainly due to respiratory cancer, but increases were also seen for cancer of the urinary organs and for cancer of the mouth and throat (table 2). All of the 59 deaths from respiratory cancer were ascribed to primary lung cancer (SMR 145, 95% CI 110–186). The 14 deaths from urinary cancer included eight bladder cancers (expected 6:57) and six cancers of other or unspecified urinary organs (ICD-8 code 189) (expected 2:98). A significant increase was recorded for multiple myeloma (table 3).

Comparisons with the occupationally active part of the 1970 census population gave less detailed but only slightly different results (table 4). (When the hand picked control cohort was used as a standard of comparison, the SMR estimates corresponding to those displayed in table 4 (ages 20 to 64) were 112 for cancer, 91 for circulatory diseases, 72 for other natural deaths, 56 for external causes of death, and 91 for all causes of death combined.)

Discussion
The results indicate that stokers have an increased risk of lung cancer and multiple myeloma. Before the results are discussed, however, it is reasonable to consider the methodological shortcomings of the study.

As regards possible sources of bias, attempts have been made to make the comparisons as valid as possible. In particular, the persons included in the control group were all active unskilled workers with no occupational exposure to combustion products. By my selection of the occupational groups included as controls, the two comparison groups were made as compatible as possible with respect to other risk factors for chronic diseases. Apart from stratification for age and calendar time, no further bias control was practicable and the possibility still exists that, for example, lifestyles differed between the stokers and the comparison group.

Table 1  Mortality of Danish stokers 1970–80. Observed number of deaths (Obs), standardised mortality ratio (SMR), and 95% confidence interval (95% CI) for the SMR

<table>
<thead>
<tr>
<th>Underlying cause of death*</th>
<th>Obs</th>
<th>SMR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer (140–209)</td>
<td>136</td>
<td>118 (99–140)</td>
</tr>
<tr>
<td>Circulatory diseases (390–458)</td>
<td>166</td>
<td>91 (77–106)</td>
</tr>
<tr>
<td>Bronchitis, emphysema, and asthma (490–5)</td>
<td>33</td>
<td>118 (78–161)</td>
</tr>
<tr>
<td>Other diseases</td>
<td>12</td>
<td>35 (16–58)</td>
</tr>
<tr>
<td>External causes of death (E800–999)</td>
<td>19</td>
<td>56 (34–88)</td>
</tr>
<tr>
<td>Total</td>
<td>366</td>
<td>93 (84–103)</td>
</tr>
</tbody>
</table>

*The code used in the eighth revision of the International Classification of Diseases (ICD–8) in parentheses.

Table 2  Cancer mortality of Danish stokers 1970–80. Observed number of deaths (Obs), standardised mortality ratio (SMR), and 95% confidence interval (95% CI) for the SMR

<table>
<thead>
<tr>
<th>Cancer site*</th>
<th>Obs</th>
<th>SMR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buccal cavity and pharynx (140–9)</td>
<td>3</td>
<td>280 (58–819)</td>
</tr>
<tr>
<td>Digestive organs (150–9)</td>
<td>30</td>
<td>88 (60–126)</td>
</tr>
<tr>
<td>Respiratory organs (160–9)</td>
<td>59</td>
<td>137 (104–177)</td>
</tr>
<tr>
<td>Male genital organs (185–7)</td>
<td>10</td>
<td>117 (56–216)</td>
</tr>
<tr>
<td>Urinary organs (188–9)</td>
<td>14</td>
<td>147 (80–246)</td>
</tr>
<tr>
<td>Lymphatic and haematopoietic tissue (200–9)</td>
<td>10</td>
<td>115 (55–211)</td>
</tr>
<tr>
<td>Other and unspecified sites</td>
<td>10</td>
<td>96 (46–177)</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>118 (99–140)</td>
</tr>
</tbody>
</table>

*The code used in the ICD–8 in parentheses.
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Table 3 Lymphatic and haematopoietic neoplasms among Danish stokers 1970–80. Observed number of deaths (Obs), standardised mortality ratio (SMR), and 95% confidence interval (95% CI) for the SMR

<table>
<thead>
<tr>
<th>Underlying cause of death*</th>
<th>Obs</th>
<th>SMR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lymphatic leukaemia (204)</td>
<td>2</td>
<td>126 (15–454)</td>
</tr>
<tr>
<td>Myeloid leukaemia (205)</td>
<td>0</td>
<td>0 (0–138)</td>
</tr>
<tr>
<td>Multiple myeloma (203)</td>
<td>4</td>
<td>388 (106–994)</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>116 (32–298)</td>
</tr>
<tr>
<td>Total (200–9)</td>
<td>10</td>
<td>115 (55–211)</td>
</tr>
</tbody>
</table>

*The code used in the ICD–8 in parentheses.

Differences in smoking habits are of particular interest because smoking is associated with chronic bronchitis and cancers of the lung and bladder. The fact that the stokers and the control group belonged to the same social class implied that the smoking habits were identical in the two groups. Because data were not available this assumption could not be checked, and with regard to chronic bronchitis and cancer of the lung and bladder, a possible confounding effect of differences in smoking habits cannot be ruled out. Smoking, however, is prevalent among unskilled Danish men, and if smoking alone had caused the increase in primary lung cancer, it would be necessary to assume that almost all of the stokers were smokers.

Regarding the so called healthy worker effect, the pronounced deficit of deaths from “other diseases” indicated that the group of stokers had been subjected to a stronger health based selection before the beginning of the study than had the control group. If the members of the control group were on average less healthy than the stokers when they were enrolled into the study in 1970 it is likely that the mortality from, for example, chronic bronchitis and circulatory diseases has been underestimated, because these diseases are incompatible with retaining a physically demanding job such as that of a stoker. Unfortunately the magnitude of the resulting negative bias cannot be established. For non-cancer deaths, comparison with the entire occupationally active 1970 census population gave quite low SMR estimates. The findings indicate that the practice of using a hand picked control cohort has reduced the healthy worker effect although it has not eliminated it.

Table 4 The mortality of stokers relative to that of all employed Danish men 1970–80, aged 20 to 64 inclusive

<table>
<thead>
<tr>
<th>Underlying cause of death*</th>
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<th>SMR (95% CI)</th>
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<td>88 (74–104)</td>
</tr>
<tr>
<td>Other natural deaths</td>
<td>39</td>
<td>56 (41–77)</td>
</tr>
<tr>
<td>External causes of death</td>
<td>17</td>
<td>43 (27–69)</td>
</tr>
<tr>
<td>(E800–999)</td>
<td>304</td>
<td>82 (74–92)</td>
</tr>
</tbody>
</table>

*The code used in the ICD–8 in parentheses.

The very low mortality from accidents may reflect that, compared with the average for unskilled Danish men, the stokers represent a stable group with a low job turnover. Furthermore, the stokers employed by central heating plants have usually lived close to their workplace. Taken together, these factors may well be compatible with a low risk of suicides, traffic accidents, and other types of violent death. In this context, it may also be of importance that the stokers’ workplaces have been stationary and placed indoors.

The quality of diagnosis was the same for the two groups because access to medical care was free and equal throughout the period studied.

Yet another methodological aspect that should be kept in mind is the insensitivity of the study. Job title and employment on the day of the census was taken as a surrogate measure for exposure and no complementary data on exposure intensity or duration were available. Furthermore, the exposed cohort comprised not only stokers; boilermen and boiler attendants who were essentially unexposed to combustion products were included in the so called exposed cohort. It is estimated that some 500 boiler-men/boiler attendants have been included in the study (about 20% of the exposed cohort). It would have been highly desirable to restrict the study cohort to comprise coal stokers only but this could not be done because the National Bureau of Statistics had coded the census records with an identical job code for stokers and boilermen/boiler attendants. Most likely the inclusion of boilermen and boiler attendants in the study cohort has led to an underestimation of the adverse effects of inhalation of combustion products.

The finding of an increased risk of lung and urinary cancer is in agreement with the findings in several studies of gas and coke plant workers, who have also been exposed to coal combustion effluents. Also, the magnitude of the SMRs for lung and urinary cancer among stokers corresponds well to the responses recorded previously for gas and coke plant workers.

The excess mortality from multiple myeloma was brought about by four deaths. Although this finding is statistically significant, it might have been due to chance. An increased risk of multiple myeloma has been recorded, however, in a cohort study of gas workers and case-control studies have indicated an association with occupational exposure to petroleum products as well as to coal and oil combustion products. It would therefore seem to be worthwhile considering possible aetiological factors in the stokers’ work atmosphere. Among the agents mentioned as possible causal agents for multiple myeloma are ionising radiation, benzene, and arsenic. Coal combustion releases several carcinogenic substances including arsenic, benzene, radio-nuclides of radon, uranium, thorium, lead and polonium and various PAHs. One or more of these
agents may have contributed to the increased mortality from multiple myeloma among stokers.

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