Past exposure to asbestos and combustion products and incidence of cancer among Finnish locomotive drivers

Pekka Nokso-Koivisto, Eero Pukkala

Abstract

Locomotive drivers in the steam engine era were exposed to asbestos during their vocational training for two years while training in workshops. Later in their career they had exposure to coal and diesel combustion products. To assess the level of earlier exposure historical working conditions were reconstructed and hygienic conditions were measured. The average exposure to asbestos (mainly anthophyllite) fibres > 5 μm was 5·0 fibres/cm³. Incidence of cancer in a cohort of 8391 members of the Finnish Locomotive Drivers' Association, 1953–91, was analysed. The incidence of lung cancer and also total cancer was below the national average, probably due to the low prevalence of smoking among the drivers in the steam engine era. A four-fold risk of mesothelioma was found, most likely caused by exposure to asbestos. Also the observed 1·5-fold incidence of non-melanoma skin cancer and 1·7-fold risk of cancer of the oral cavity and pharynx may be related to occupation.


This study arose from a case of mesothelioma in a locomotive driver, and from concern that conservation and recycling of old locomotives and coaches causes exposure to asbestos. During the steam engine era all trainee locomotive drivers in Finland were exposed to asbestos in the railway workshops. When working in traffic operations, the drivers were exposed to combustion products and to coal tar. New diesel locomotive drivers are exposed to exhaust fumes from the engine.

Asbestos exposure is suspected to have caused an increased risk of mesothelioma and lung cancer among locomotive drivers and other railway workers.1 Combustion products of coal and diesel have been reported to be associated with lung cancer2 and cancer of the bladder.3,4 The incidence of non-melanoma skin cancer is increased among people exposed to combustion products of coal and creosote.5 Cancers of the buccal cavity and pharynx and lymphatic tissue have been found in excess among railway workers.6,7 Our study has two components. The lifetime work exposures of locomotive drivers, as a constellation of occupational causes of cancer, were investigated through measurements of hygienic conditions in the steam engine era and through evaluating routine hygienic investigations of working conditions in the diesel engine era. Also, the incidence of cancer among Finnish locomotive drivers was compared with that of the total Finnish population from 1953 to 1991.

Methods

ASSESSMENT OF EXPOSURES

All locomotive drivers of the Finnish state railways are educated according to defined curricula, which before the 1970s included two years practising in a railway workshop. The main part of the training took place in the engine maintenance department of the workshop. In the 1960s steam engine maintenance gradually ended. The drivers who started their training at the beginning of the 1970s did not take part in steam boiler upkeep. The trainees graduated to assistant locomotive drivers, started regular train operations, and were later promoted to locomotive drivers.

To study the hygienic conditions in the steam engine era the working conditions were reconstructed in two workshops with the assistance of older workers who used to take part in the earlier standard procedures. During the procedure the outer covers of the boilers of two engines were dismantled. Asbestos layers were loosened and torn away and collected in separate containers. The process looked dusty. The former workers confirmed that the reconstructed procedures resembled old routine dismantling. The workers pointed out that there were locomotives under maintenance regularly and that the dust hovered all over the workshop.

For the hygienic assessment of dismantling, eight personal air samples were collected and asbestos exposure was measured with standardised techniques. The average number of fibres > 5 μm was 5·0 (range 2·5–7·5)/cm³, indicating medium exposure. The samples contained two types of asbestos—namely, anthophyllite and chrysotile fibres. Also, the type of asbestos exposure was analysed from the samples of insulation material of three demolished engines. The analysis of these samples indicated that anthophyllite was the main type of asbestos used in insulation material of boilers. Chrysotile was detected in woven strings around pipes and ventilators. Asbestos concentrations in cabins of diesel locomotives with asbestos insulation on exhaust pipes has been measured. The number of fibres was undetectable (< 0·1 fibres/cm³).
The concentration of benz(a)pyrene and diesel engine exhaust dust exposure in rolling stock and during a journey was measured in the cabin of a renovated steam locomotive with standard occupational hygiene methods. While cleaning and decluttering a fire box, which took less than half an hour a day, the concentrations of benz(a)pyrene varied from 0.006 to 0.025 \( \mu \text{g/m}^3 \) and dust concentrations from 1.0 to 1.6 mg/m\(^3\). During the journey the concentrations of benz(a)pyrene were lower, from 0.005 to 0.010 \( \mu \text{g/m}^3 \). Dust concentrations varied from 0.7 to 2.8 mg/m\(^3\). Routine hygiene measurements in cabins of diesel engines and in rolling workshops in Finnish railways indicated that the concentrations of particles and benz(a)pyrene in diesel engines were similar to those in the steam engine. No nitrogen oxides were detected during steam engine operations, but according to routine hygiene measurements in Finnish railways the diesel engine drivers are exposed to nitrogen compounds emitted by the engines in the cabins and rolling stock.

As well as the exposure directly linked to train operations, locomotive drivers were exposed to organic substances such as lubricating oils, coal tar (creosote), and coal.

**COHORT STUDY OF INCIDENCE OF CANCER**

The cancer risk of locomotive drivers was studied in a retrospective cohort study. The cohort consisted of all members of the Finnish Locomotive Drivers' Association between the years 1953 and 1991—that is, all Finnish drivers since 1953. Retired locomotive drivers remain members of the association up to their death. All drivers were men. The cohort consisted of 8693 members; 302 members (3.5%) were excluded because of inadequate personal identification data. Follow up for death and emigration was performed in a record linkage with the Central Population Register of Finland.

The calculation of person-years started at the beginning of the membership or on 1 January 1953, whichever was later, and ended at death or emigration or on 31 December 1991, whichever occurred first.

At the Finnish Cancer Registry cancer cases of the cohort were identified by means of an automatic record linkage with a unique personal identification number assigned to everyone resident in Finland since the beginning of 1967. For those people who had died between 1953 and 1966 the follow up was performed manually with names, dates of birth, and places of residence as keys. The observed number of cases and person-years at risk were counted for five year age groups for three 15 year follow up periods since first employment, separately for 1953–65, 1966–78, and 1979–91. It should be noted that all the Finnish locomotive drivers start their training at about the same age, from 16 to 20. This means that there is no need to report results by both follow up time since first employment and age.

The expected numbers of cancer cases for both follow up periods were calculated by multiplying the number of person-years in each age group by the corresponding average incidence of cancer in Finland during the period of observation. The specific cancer types selected for study were cancers earlier reported to be linked with asbestos or derivatives of coal and diesel combustion products including creosote. These are mouth and pharynx, stomach, colon, lung and trachea, mesothelioma, prostate, kidney, bladder, ureter and urethra, skin melanoma, skin (non-melanoma), lymphatic tissue (non-Hodgkin's), Hodgkin's disease, and leukaemia.

To calculate the standardised incidence ratio (SIR) for each age group, the observed number of cases was divided by the expected number. Significance was tested by the Mantel–Haenszel \( x^2 \) test, on the presumption that the number of observed cases followed a Poisson distribution.

**Results**

The number of person-years under follow up for 8391 men in the cohort was 212 800 (table 1). The mean duration of follow up was 25.4 years.

During the 38 year observation period, 915 cases of cancer were found; the observed number was 962 (table 2). The SIR for total cancer was significantly lower than expected only in the first period, 1953–65 (131 observed cases (Obs) \( \times 1.63 \) expected (Exp), SIR 0.81, 95% confidence interval (95% CI) 0.67–0.94). In later periods the SIR for total cancer was close to unity. The reduction in the risk in the first period was totally attributable to cancers of the stomach (SIR 0.60, 21 Obs \( \times 0.35 \) Exp, 95% CI 0.37–0.92) and lung (SIR 0.64, 29 Obs \( \times 0.46 \) Exp, 95% CI

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### Table 1  Person-years under follow up among the 8391 Finnish locomotive drivers, 1953–91, by period and follow up time since first employment

<table>
<thead>
<tr>
<th>Follow up time (%)</th>
<th>0–14</th>
<th>15–29</th>
<th>30+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1953–65</td>
<td>3533</td>
<td>2410</td>
<td>7506</td>
<td>66940</td>
</tr>
<tr>
<td>1966–78</td>
<td>14957</td>
<td>35756</td>
<td>18516</td>
<td>69229</td>
</tr>
<tr>
<td>1979–91</td>
<td>2511</td>
<td>14655</td>
<td>36819</td>
<td>76585</td>
</tr>
<tr>
<td>1953–91</td>
<td>75401</td>
<td>74512</td>
<td>62841</td>
<td>212754</td>
</tr>
</tbody>
</table>

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### Table 2  Expected (Exp) and observed (Obs) numbers of cancer cases, 1953–91, among locomotive drivers and the standardised incidence ratios (SIR) with their 95% CIs, by site

<table>
<thead>
<tr>
<th>Primary site (ICD-7)</th>
<th>Obs</th>
<th>Exp</th>
<th>SIR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sites (140–204)†‡</td>
<td>915</td>
<td>962</td>
<td>0.95 (0.89–1.01)</td>
</tr>
<tr>
<td>Oral cavity and pharynx (143–148)</td>
<td>17</td>
<td>10</td>
<td>1.75 (1.02–2.80)</td>
</tr>
<tr>
<td>Stomach (151)</td>
<td>86</td>
<td>112</td>
<td>0.77 (0.61–0.94)</td>
</tr>
<tr>
<td>Colon (153)</td>
<td>36</td>
<td>37</td>
<td>0.98 (0.69–1.36)</td>
</tr>
<tr>
<td>Rectum (154)</td>
<td>29</td>
<td>34</td>
<td>0.85 (0.57–1.22)</td>
</tr>
<tr>
<td>Lung and trachea (162.0–1)</td>
<td>236</td>
<td>274</td>
<td>0.86 (0.75–0.97)</td>
</tr>
<tr>
<td>Mesothelioma (162.2, 158)</td>
<td>8</td>
<td>2</td>
<td>4.05 (1.75–9.97)</td>
</tr>
<tr>
<td>Prostate (177)</td>
<td>122</td>
<td>109</td>
<td>1.12 (0.92–1.32)</td>
</tr>
<tr>
<td>Kidney (180)</td>
<td>38</td>
<td>31</td>
<td>1.25 (0.88–1.70)</td>
</tr>
<tr>
<td>Bladder, ureter, urethra (181.0) *</td>
<td>48</td>
<td>44</td>
<td>1.08 (0.80–1.43)</td>
</tr>
<tr>
<td>Skin melanoma (190)</td>
<td>17</td>
<td>17</td>
<td>0.99 (0.71–1.37)</td>
</tr>
<tr>
<td>Skin (non-melanoma) (191) †</td>
<td>21</td>
<td>15</td>
<td>1.35 (1.04–1.75)</td>
</tr>
<tr>
<td>Non-Hodgkin's lymphomas (200,202)</td>
<td>19</td>
<td>24</td>
<td>0.78 (0.47–1.21)</td>
</tr>
<tr>
<td>Hodgkin's disease (201)</td>
<td>7</td>
<td>8</td>
<td>0.83 (0.54–1.22)</td>
</tr>
<tr>
<td>Leukaemia (204)</td>
<td>21</td>
<td>24</td>
<td>0.87 (0.54–1.32)</td>
</tr>
</tbody>
</table>

* Excludes papillomas of the bladder.
† Excludes basal cell carcinomas of the skin.
All Primary site and trachea
Mesothelioma Kidney Bladder, ureter, oropharynx

In Table 3 the unity: approached for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for other analysed cancers were for 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Past exposure to asbestos and combustion products and incidence of cancer among Finnish locomotive drivers

explained by changes in exposures (asbestos, combustion products) and in smoking habits. Smoking, diesel exhaust fumes, and asbestos have been suggested to have interactive effects on risk of lung cancer.22 Diesel locomotives, causing exposure to diesel exhaust, were introduced to the railways in the 1950s. The exposure to combustion products among locomotive drivers is, however, only slightly above the national average. The exposure to benz(a)pyrene is above that of Finnish town air.23 In a Swedish study of traffic workers with the same level of diesel exhaust exposure as Finnish locomotive drivers there were no detected signs of urinary mutagenicity or increased thioether excretion in urine.24

In the steam engine era Finnish locomotive drivers were not heavy smokers. Ancodical evidence indicates that draughts in the cabin prevented drivers from appreciating smoking. It may be assumed that the increased smoking in the less draughty cabins of diesel locomotives with less physical work and more passive monitoring would have increased the risk of lung cancer close to the national average. A cross sectional study of Finnish locomotive drivers in the year 1976 showed that 40% of the non-smokers (69%) had stopped smoking, and 26% had never smoked.25 These percentages are similar to those of the whole Finnish population in 1979.26

Asbestos insulation workers in the United States and Canada have an increased risk of death from cancers of the oesophagus, colon and rectum, larynx, oropharynx, kidney, and perhaps stomach.26 Our study showed an increased SIR for oropharyngeal cancer but not for the other sites, possibly due to different exposures. On the other hand our study shows an increased risk of non-melanoma skin cancer, consistent with other experiences, in occupational medical medicine. Locomotive drivers are exposed to different organic substances (lubricating oils, creosote) that can cause dermal irritation and toxiidermia.27 A slight excess of squamous cell skin cancer has been found before among engine drivers28 and creosote exposed impregnators.29

Among the members of the Brotherhood of Locomotive Engineers in the United States there were significantly raised proportionate mortality ratios for cancers of the bladder (2.05), kidney (2.65), digestive organs (1.30), and lymphoreticular malignancies (2.29).30 Mortality ratios for the respiratory system were not increased. The increased risks of cancer of the lower urinary tract associated with occupational exposure of locomotive drivers has been confirmed by later studies,30 even when smoking was controlled for.31 We found only slightly higher risks for cancers of the bladder (SIR 1.08) and kidney (SIR 1.25), which may, taking into account the low prevalence of smoking in our cohort, include a component of occupational aetiology.

In conclusion, the fourfold risk of mesothelioma in locomotive drivers is likely to be triggered by short term asbestos exposure. Also the increased incidence of non-melanoma skin cancer and oropharyngeal cancer might be work related. Because of the low prevalence of smoking in the steam engine era the risk of lung cancer has until now been rather below the national average. The exposure to diesel engine exhaust fumes seems to be small and its role in causing cancer negligible. The classic occupational exposures have been waning with new working conditions and gradual electrification of the railways in the 1970s and the 1980s but this benefit is not strong enough to compensate for the increasing risks associated with modern working conditions including more enclosed cabins, more monitoring, and more smoking.

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