The rise and fall in incidence of malignant mesothelioma from a British Naval Dockyard, 1979–1999

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Background
The incidence of malignant mesothelioma in Britain is predicted to rise over the next 15–25 years because of past failure to protect the workforce against inhalation of asbestos. In British Naval dockyards, alternative insulation materials and respiratory protection were introduced from the mid-1960s.

Aims
This study was carried out to investigate the effects of these control measures on mesothelioma deaths in dockyard workers.

Methods
Cases of mesothelioma of the pleura and peritoneum between 1979 and 1999 in workers from the Devonport Naval Dockyard, south-west England, were sought from coroners’ and medico-legal records.

Results
Three hundred and one cases were identified, 7% peritoneal. The peak incidence occurred in 1991 with 25 cases per annum (quadratic model fit $R^2 = 74.2\%$, $P < 0.001$) and we predict that by 2003 the incidence will fall to fewer than five cases per annum. The mean time between first exposure and presentation was 48.5 years [95% confidence interval (CI) = 47.3–49.8], but this was significantly shorter in the more heavily exposed trades, when compared with the less heavily exposed (42 years, 95% CI = 39.0–45.0, versus 49.5 years, 95% CI = 48.2–50.9). Those with higher exposure were also at significantly greater risk of peritoneal disease ($P < 0.023$, Fisher’s exact test).

Conclusion
The reduction in incidence of mesothelioma is greater than can be accounted for by reduction in numbers of dockyard workers over the last 50 years. Changes in insulation materials and improved industrial hygiene measures introduced into the Devonport Dockyard from the mid-1960s have resulted in an earlier decline in the incidence of malignant mesothelioma than that predicted for the British workforce as a whole.

Key words
Asbestos; dockyard; incidence; latency; mesothelioma; peritoneum.

Introduction
Malignant mesothelioma of the pleura and peritoneum is becoming more common in Britain due to the widespread use of asbestos in the twentieth century and failure to protect workers at risk until the last quarter of the century. It has been predicted that the incidence will continue to rise, perhaps until 2020, when it could account for up to 3000 deaths per annum [1]. There are similar predictions for Europe [2].

The Devonport Naval Base in Plymouth has been the largest British naval dockyard, employing ~19 000 at the time of the Second World War and ~15 000 in 1966 [3].
In 1980, Sheers and Coles [3] published a detailed description of asbestos usage in the dockyard, the numbers of men in different trades in the mid-1960s and the rising incidence of mesothelioma from 1960 to 1978. All three forms of asbestos—crocidolite, amosite and chrysotile—have been used from the beginning of the century, but from 1944 to 1963 large amounts of crocidolite were applied for fire protection and insulation in naval vessels, and between 1950 and 1963 there was an increase in the use of amosite for machinery insulation. Calcium silicate and fibreglass began to replace asbestos from 1963, but asbestos continued to be removed in refit work during the 1970s and 1980s.

Respiratory protection was introduced for the more heavily exposed workers in the 1960s; over the ensuing period, the precautionary measures were extended to all potentially exposed workers and more efficient respiratory protection was enforced. Detailed occupational histories taken from hundreds of dockyard workers indicate that there were ample opportunities for inhalation of asbestos dust well into the 1970s (C. McGavin, personal observation).

Sheers [4] gives details of the 100 cases from the yard, the annual incidence rising from two in 1962 to 12 in 1977. Only three (3%) were peritoneal. The present study extends the work of Sheers, describing the continuing occurrence in the same workforce from 1979 to 1999. We hypothesized that this introduction of non-asbestos insulation materials and the enforcement of respiratory protection would have prevented cases of mesothelioma and produced an earlier peak and decline than in the British workforce in general, where respiratory protection was less rigidly applied.

**Methods**

A case was defined as an individual who had worked in the Devonport Dockyard for at least 6 months and who had a pathologically confirmed diagnosis of malignant mesothelioma between 1979 and 1999. Case ascertainment was by inspection of records by the relevant local coroners in south-west England—namely, Plymouth, Bodmin, Truro and Barnstable—and by review of medico-legal files held by local chest physicians. Recent dockyard pension schemes were examined. Hospital and histology records yielded no further cases. Occupation, dates of exposure inside and outside of the dockyard, dates of onset of symptoms, date of death and site of disease were recorded. For the calculation of total years of exposure, the date of the last exposure was taken as 1972.

With regards to intensity of exposure, the classification into ‘continuous’ and ‘intermittent’ exposure by Sheers and Coles [3] has been adopted. The continuously exposed group includes laggers, sprayers and painters, while the intermittent group includes shipwrights, boiler-makers, fitters and welders.

**Statistical analysis**

Regression analysis was used to determine the best-fit model for the trend in numbers of mesothelioma deaths over time and to predict the number of likely deaths for the year 2003. A Student’s t-test was used to test for differences between the latencies in mesothelioma onset after exposure for the different exposure groups.

**Results**

Three hundred and one deaths in the period 1979–1999 were identified. Two workers were female (three mesothelioma deaths during the study period in wives of workers have not been included in the analysis). Insufficient information was available about occupation in six cases and about exposure in 14 cases. Seventy-one men had been exposed outside as well as inside the yard, but satisfactory data on this exposure are available in only 63 cases.

The mean number of years of asbestos exposure was 22.6 (range 1–57); in those men also exposed outside the yard, the total mean exposure was 28.4 years. The mean age at death was 68.2 (range 44–95). Mean latent period from first exposure to disease presentation was 48.5 years (95% CI = 47.3–49.8).

Table 1 gives deaths according to main trade. In the 41 workers known to have been in a ‘continuously exposed’ trade, the latent period was significantly shorter (42.0 years, 95% CI = 39.0–45.0) than in the 241 workers in an ‘intermittently exposed’ trade (49.5 years, 95% CI = 48.2–50.9, \(P < 0.001\)).

Figure 1 shows the number of deaths by years and shows a peak incidence of deaths in the years 1989–1994. Regression analysis supports the view that the death rate

![Table 1. Deaths by trade](image)
has peaked, a quadratic model providing a good fit to the data of 1979–1999 ($R^2 = 74.2\%, P < 0.001$). The model suggests that the death rate has fallen by 35% between 1991 and 1999. Figure 2 shows the number of cases by year of presentation. The years 1998 and 1999 have been omitted, because ascertainment has been by death and cases still living will not have been detected. Again, a quadratic model provides a good fit to the data ($R^2 = 57.4\%, P < 0.001$). Trend analysis forecasts the annual deaths will fall to less than five by 2003.

Twenty-one (7%) cases of peritoneal mesothelioma were identified. There was a significant excess of workers from the continuously exposed group (7 out of 41 for whom data are available; $P < 0.023$, Fisher’s exact test). The mean latent period for peritoneal disease was the same as for pleural (48.5 versus 48.6 years).

**Discussion**

This study investigated a large number of mesothelioma deaths in a well-defined and stable work force.

The results indicate that the incidence of malignant mesothelioma rose from 1962 to 1989–1994 and is now declining.

The importance of this study is that it represents the first recorded decline in mesothelioma deaths in a UK workforce.

In our study, it is possible that ascertainment will have been incomplete because of failure to diagnose or report cases to the coroner. This is likely to have been a greater problem in the early years of the study, when awareness of the disease was less, particularly in the case of peritoneal disease. However, these factors would have obscured an earlier peak and subsequent decline. Other cases may have escaped detection by having moved from the area, although earlier epidemiological work in Devonport Dockyard employees suggests that fewer than 1 in 13 cases may have been missed in this way [5].

The authors have been unable to obtain accurate figures from the Ministry of Defence for the workforce in the Devonport Dockyard since the Second World War, but it is known that the workforce had fallen by 21% from 19 000 at the end of the Second World War, to 15 000 in 1966. Our data suggest that the mesothelioma incidence has fallen by one-third since 1991 and it is therefore improbable that the fall in incidence of mesothelioma is accounted for simply by reduction in workforce numbers.

Our data indicate that heavy exposure to asbestos is associated with a shorter latent period before disease presentation. It has previously been suggested [6] that heavy exposure is associated with a higher risk of peritoneal disease and our data would support this hypothesis.

In conclusion, this study provides good evidence that the reduction in asbestos exposure resulting from change in insulation materials and the introduction of respiratory protection in the Devonport Dockyard in the 1960s and 1970s is responsible for a fall in incidence of mesothelioma in the last decade. This reduction in mortality is well in advance of that predicted for the disease in general, in British workers who have not had the benefit of better safety management, including replacement of asbestos and the introduction of more effective respiratory protection.

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