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Experience with Asbestos Disease and Its Control in Great Britain's Naval Dockyards

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ENVIRONMENTAL CONDITIONS IN THE RECENT PAST

Workers in British naval dockyards have installed and removed asbestos in warships for some 90 years, and in doing so they have frequently been exposed to very high concentrations of asbestos dust.

Crocidolite asbestos was extensively applied by a spray process to deckheads and bulkheads for environmental insulation from 1940 to 1960. Records show that asbestos dust concentrations of 177-322 f/cc (fibers 2-10 μ m long) occurred during the spray process and these results are similar to those reported by Reitze *et al.* (1972) for asbestos spraying operations in New York City. Fiber concentrations during the removal of sprayed crocidolite asbestos in British dockyards range from 50-500 f/cc, with local concentrations up to 2,000 f/cc while sweeping and bagging asbestos debris.

Samples taken at considerable distances from the dust source show that the dust is widely dispersed throughout the ships, thus exposing many other men not directly working with asbestos to dangerous concentrations of the dust. A concentration of 30 f/cc was recorded two decks above the compartment in which 311 f/cc were produced during the removal of sprayed crocidolite asbestos (Harries, 1971a). An idea of the degree of risk involved in these processes may be obtained by comparing these values with the recommended upper limit of 0.2 f/cc for work with crocidolite asbestos laid down by the British Department of Employment Factory Inspectorate.

Machinery insulation was applied mainly as preformed sections containing 15-90% amosite asbestos and covered with chrysotile asbestos cloth. Fiber concentrations of 2-20 f/cc were recorded during these processes. Removal of pipe and machinery insulation created fiber concentrations of 100-200 f/cc. The recommended upper limit for amosite and chrysotile asbestos dust is 2 f/cc.

Other dockyard processes involving a variety of asbestos materials created locally high dust concentrations (Harries, 1971a), and an important example of an unexpected source of asbestos exposure was discovered in naval store sheds in which unprotected asbestos roof insulation had been damaged by birds (Lumley *et al.*, 1971).

PRESENT ENVIRONMENTAL CONDITIONS

The British Ministry of Defence (Navy) has reviewed all the uses of asbestos in Naval Dockyards and, wherever possible, has introduced substitute materials. Very little, if any, asbestos is now included in new ships built for the British Navy, and no crocidolite or amosite asbestos is used. These measures, together with

improved codes of practice for insulation workers, have resulted in a very considerable reduction in asbestos fiber concentrations in British Naval Dockyards (Harries, 1971a).

Environmental monitoring in ships under refit now shows detectable asbestos fiber concentrations only during the removal of existing asbestos materials. This problem will be self-limiting as replacement materials will not contain asbestos. Respiratory protection by air-fed hoods is obligatory for any work involving the removal of crocidolite asbestos, and dust filter respirators are compulsory where amosite or chrysotile asbestos fiber concentrations exceed 2 f/cc.

Unfortunately, most of the substitute high-temperature insulating materials are very dusty, especially those containing calcium silicate. Appropriate respiratory protection is provided for men applying or removing these materials and steps are taken to prevent the widespread dispersal of dust throughout the ships in order to protect other workers. Dust filter respirators are compulsory for workers exposed to time weighted average concentrations of "asbestos-free" insulating materials exceeding 5 mg/m³. Changing, washing, and laundry services are provided for all insulation workers, and respirators are issued and maintained from a central department to ensure that the correct equipment is being used and to see that it is properly maintained.

EXTENT OF THE HEALTH HAZARDS ASSOCIATED WITH ASBESTOS

Pilot radiographic surveys were conducted in four British Naval Dockyards in order to obtain some idea of the numbers of men affected by asbestos disease; these studies showed an overall prevalence of 3% asbestos abnormalities in those examined. Prevalences from 5-24% were discovered in men with more than 25 years from first exposure to the dust (Sheers and Templeton, 1968; Harries *et al.*, 1972). Complete surveys of these dockyards are now proceeding and preliminary results show that 893 (8%) of 10,849 persons so far examined show radiological asbestos abnormalities. There is clearly a large problem.

Asbestos—Pulmonary Fibrosis

At Devonport Dockyard in Plymouth, England, 156 men have been awarded disability pensions for asbestosis in the 10 years up to September 1973. Lagers and sprayers form the highest proportion of these cases, but Table 1 shows the other occupations involved and it can be seen that most of these were exposed to asbestos because they worked in close proximity to the insulation workers.

Studies in Devonport have shown relationships between the duration and intensity of exposure and the development of symptoms, physical signs, radiographic abnormality, and lung function changes, and that asbestos-related pleural abnormalities are accompanied by a reduction in the ventilatory capacity (Harries, 1971b).

Asbestos Pleural Abnormalities

While cases of pulmonary fibrosis will continue to occur for some time, patients presenting with advanced disease will rapidly become uncommon because of the great improvements achieved in environmental conditions. The majority of radiographic abnormalities detected in the present survey, however, are pleural

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TABLE 1
OCCUPATION OF 156 MEN WITH ASBESTOSIS IN PLYMOUTH 1964—1973

Laggers	36
Asbestos sprayers	16
Shipwrights	15
Engine fitters	15
Ships cleaners	12
Electrical fitters	11
Joiners	8
Caulker/riveters	6
Painters	6
Slingers	6
Welders	5
Boilermakers	4
Engineers	3
Other occupations	13
Total	156

rather than parenchymal, and this is probably a reflection of intermittent rather than heavy and prolonged type of exposure in this population.

In Plymouth, the data on 457 men with asbestos-related pleural abnormalities are being analyzed. Calcified plaques are present in 103, uncalcified plaques in 285, and diffuse fibrosis with or without effusions in 69. With very few exceptions, these men have all been exposed to asbestos in the dockyard, the majority of them by working near asbestos laggers, sprayers, or strippers. The average time from first exposure to the dust to detection of the abnormality is more than 25 years, except for those with diffuse pleural reactions in whom it is 15–20 years.

Mesothelioma

There have been 55 deaths in Plymouth from mesothelial tumors in the 10 years up to September 1973 (Table 2). The growths involved the pleura, except for one

TABLE 2
MESOTHELIOMA DEATHS IN PLYMOUTH

1964	2
1965	3
1966	3
1967	5
1968	4
1969	9
1970	7
1971	7
1972	8
1973	7*
1964–1973	55

* Plus 11 patients still alive in September 1973.

peritoneal tumor. The average age at death was 63 years (range 40–83 years), and the average time from first asbestos exposure to death was 39 years (range 20–64 years). Only two men, one lagger and one sprayer, could be regarded as asbestos workers. The remaining dockyard occupations include those men who worked with or near the insulators and sprayers, and those who occasionally fitted and removed asbestos materials in ships (Table 3).

Review of the 44 available series of chest radiographs from those 55 cases reveals that 15 of them had previous films showing pleural plaques. The prevalence of plaques in the mesothelioma cases (34%) is higher than the expected prevalence in similarly exposed groups in the survey population (12%).

Diffuse pleural reactions, with or without small effusions, were present in previous films of 20 (45%) of the 44 cases; in each of the remaining nine cases the first radiological abnormality was the tumor, with or without a large effusion. Some of the current survey radiographs show similar pleural reactions or small effusions, but it must be made clear that not all of these are expected to progress to mesothelioma. Several patients have been observed with repeated small effusions which partially or completely resolve, but others are left with very slowly progressive pleural fibrosis (Mackenzie and Harries, 1970). Similar reactions in asbestos workers have been reported elsewhere by Eisenstadt (1964), Collins (1968), Gaensler and Kaplan (1971), and Sluis-Cremer and Webster (1972).

DISCUSSION

The virtual elimination of asbestos from new ship construction and the elaborate precautions taken during manipulation of existing asbestos materials means that new entrants to the industry should not be exposed to appreciable asbestos dust concentrations now, or in the future. But large numbers of men have already been exposed to the dust and some of them are being affected by asbestos disease.

TABLE 3
OCCUPATIONS OF MEN DYING WITH MESOTHELIAL TUMORS IN PLYMOUTH 1966–1973

Dockyard occupations		Other occupations	
Shipwrights	14	Railway locomotive fitter	1
Boilermakers and assistants	9	Electricity board stoker	1
Engine fitters	8	Bank manager	1
Electrical fitters	5		
Welders	3	Total	3
Caulker/riveters	3		
Drivers/fork trucks (mobile cranes)	3		
Slingers	2		
Ship cleaners	1		
Stoker	1		
Machinist	1		
Asbestos sprayer	1		
Lagger	1		
Total	52		

Because of the latent period associated with asbestos disease, many more of those exposed are expected to become affected over the next 30 years.

Cases of pulmonary fibrosis will decline in number, and already most of the abnormalities are pleural. Many pleural plaques, however, are not detected on standard chest radiographs (Hourihane *et al.*, 1966), so that the large number of those abnormalities seen in the present survey (up to 8% of the dockyard population) is an underestimate of their true prevalence.

The significance of the plaques is still uncertain. Jones and Sheers (1972) suggest that they are not clinically harmful, but act as a marker to draw attention to possible asbestos exposure. But Hourihane and his colleagues (1966) point out that radiologically detectable plaques are usually accompanied by microscopical interstitial fibrosis of the lungs, even though there is no obvious radiological parenchymal change. Becklake *et al.*, (1970) showed that persons with pleural changes had poorer lung function than those without those abnormalities, and this has also been the experience at Devonport Dockyard (Harries, 1971b). In addition, an increased risk of developing bronchial carcinoma and pleural mesothelioma has been reported in shipyard workers with pleural plaques (Fletcher, 1972), and insulation workers are known to have an increased risk of developing bronchial carcinoma and mesothelioma (Selikoff *et al.*, 1972).

The plaques seen on previous chest radiographs of men with pleural mesothelioma are indistinguishable from those seen in the current radiographic surveys. Diffuse pleural reactions and effusions seen on survey radiographs are similar in appearance to those seen initially in some patients who subsequently develop pleural mesothelioma. Large numbers of pleural abnormalities are being detected in our surveys, indicating that the persons involved are reacting to the dust within their thoracic cavities. The possibility of many of them eventually developing mesothelial tumors is a matter of grave concern.

It is possible to suspect the development of pleural mesothelioma by radiologically observing progressive pleural tumor growth, and to confirm the diagnosis by cytological examination of the pleural fluid. But it is not yet possible to predict which men with asbestos pleural abnormalities will develop mesothelioma or other tumors, nor is it possible yet to say for certain, despite Fletcher's suggestion (1972), whether or not they have a higher risk of developing these tumors than men exposed to asbestos who do not yet show pleural abnormalities.

Radiology is a very useful epidemiological tool in confirming the response to the hazard, and it is helpful in monitoring individuals to detect the onset of progressive disease. But by the time the disease is seen radiologically to be progressive it has reached the stage where there is no effective treatment (Elmes, 1972).

Other methods of monitoring the exposed populations are required, and it is possible that immunological techniques may provide such methods. Pernis, Vigliani, and Selikoff (1965) reported an increased prevalence of rheumatoid factor in asbestos workers, and Turner-Warwick (1973) has shown an increased prevalence of antinuclear factor as well as rheumatoid factor in patients with asbestosis. Serum gamma globulin levels are higher in asbestos-exposed men with plaques than in those without plaques, and higher still than in nonexposed controls (Navratil, 1970). Unfortunately, the immunology of mesothelial tumors has not yet

been established, but if a specific tumor antibody could be identified the detection of those antibodies in exposed persons could be used to discover susceptible persons, and then it might be possible to introduce treatment by using tumor-specific antigen to boost the host's reactions to the tumor.

The priorities for medical research into the asbestos diseases would appear to be for urgent fundamental research into tumor antibodies and the production of tumor antigens; or to identify and rectify, if possible, any defects in the immunological status of persons with mesothelial tumors. Populations of large numbers of asbestos-exposed persons, many of whom are developing pleural plaques and mesothelial tumors, as exist in our Naval Dockyards, not only constitute suitable study groups but are also those populations which would directly benefit from any advances made in the detection and treatment of these diseases. The research programme in British Naval Dockyards includes immunological studies, in addition to the continuing work on the effects of asbestos exposure on lung function, and these projects are linked to the current morbidity surveys and long-term mortality studies of the Dockyard population.

CONCLUSIONS

Improvements in asbestos hygiene in British Naval Dockyards will prevent asbestos disease in future employees. It is our clear duty to attempt to help those persons already exposed to the dust, some of whom will develop fatal malignant disease. Research is required into methods of detecting susceptible persons among those exposed to the dust, and to develop techniques whereby the malignant processes associated with asbestos exposure may be prevented, modified, or reversed once they have occurred. Research into the immunological aspects of asbestos disease should receive urgent priority.

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