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Mesothelioma after Crocidolite Exposure during Gas Mask Manufacture[1]

ALISON D. MCDONALD

Department of Epidemiology and Health, McGill University, Montreal, Canada

AND

J. CORBETT MCDONALD

TUC Centenary Institute of Occupational Health, London School of Hygiene and Tropical Medicine, London, England

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Of 199 persons employed in the manufacture and handling of Canadian military gas mask canisters containing pure crocidolite, 1939 to 1942, by the end of 1975, 56 had died, 120 were still alive, and 23 could not be traced. Nine (16%) of the deaths were probably due to malignant mesothelioma, six involving the peritoneum. The risk of mesothelioma after crocidolite exposure appears to be many times greater than that after chrysotile.

INTRODUCTION

Evidence has accumulated that the mineral types of asbestos fibre have different mesothelioma-producing potential—greatest for crocidolite, followed by amosite, chrysotile, and anthophyllite (McDonald and McDonald, 1977). However, there have been very few studies of human exposure to single mineral types of fibre. For some years we have observed the occurrence and causes of death in a cohort of over 11,000 employees in the Quebec chrysotile mining and milling industry. About 10% of this group had worked in a small asbestos products factory in one of the mining towns. Of 10,259 members of the cohort traced to the end of 1975, 4247 had died since 1935 and the cause of death was ascertained in 98% (McDonald *et al.*, 1971; McDonald *et al.*, 1973; McDonald *et al.*, 1974; Liddell *et al.*, 1977; McDonald *et al.*, 1978). Recently we identified another cohort of 199 persons who were exposed to crocidolite between 1939 and 1942 in three separate factories including the one in the mining town mentioned above. In two plants filter pads containing pure crocidolite were made; in a third plant they were packed into canisters which were assembled into gas masks for the Canadian army. Of the 199 persons, 174 were traced to the end of 1975—56 were found to have died and the cause of death was identified. This study is described and the pattern of mortality compared with that in the Quebec chrysotile mining and milling industry.

METHODS

A malignant pleural mesothelioma was diagnosed in 1974 in a scientific officer who was one of a small group of men in Ottawa responsible for setting up and

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managing, at the time of the second world war, an assembly plant for gas masks for the Canadian army. The specifications for these gas masks were the same as for the British military model which was assembled from September 2, 1940 through May 5, 1943 in a factory in Nottingham. Jones *et al.* (1976) reported many cases of mesothelioma in persons who had assembled gas masks in this factory. The respirator canisters contained crocidolite 20% by weight and wool 80%. Chrysotile was used in the Nottingham factory for civilian gas masks from February 1937 through March 1940, but in Ottawa the only type of asbestos used was crocidolite.

Filter pads were made in two factories in Quebec. Crocidolite and wool were carded in layers, cut into individual pads, and packed in boxes which were delivered to the assembly plant in Ottawa. They were unpacked in a large room where they were reduced to the correct weight by removing some of the surface layer, put into canisters, and tested. There was no special exhaust ventilation but those who had worked there said that it had not appeared dusty. The plant was in operation from the end of 1939 through 1945 but crocidolite was used only until spring 1942, after which time no asbestos was used in the filters.

Extensive enquiries during 1976 failed to reveal any records of civilian employees of the Ottawa plant—neither individual records nor paybooks. Records were still held on military staff but provided no practical means of identifying those who had worked in the plant. Starting with persons named by the man whose tumour was diagnosed in 1974, a list was made of all those who had worked in the plant whose names were known. Attempts to trace the 54 persons listed, mainly by personal enquiries, revealed that 25 were alive and 16 dead; 13 could not be traced.

In the factory at Asbestos, Quebec, which since the first world war has processed mainly chrysotile asbestos produced locally, filter pads were made in the textile department from 1939 through 1941. For our studies in the Quebec mining industry, job histories had been extracted from personnel records for all persons who had worked for at least one calendar month. It proved to be impossible to distinguish those who had worked on the gas mask filters, so everyone who had worked in the textile department during the relevant period—1939 through 1941—was assumed to have been exposed. In view of the conditions current at that time this was not an unreasonable assumption. The 84 persons who were born 1891 to 1920 had already been traced to the end of 1975; one was lost, 62 were alive, and 21 had died. A further 29 persons, born since 1920, had also been employed in the textile department; 23 of these were found alive at the end of 1975 and 6 had died.

At a factory in Montreal which has manufactured mainly brake linings since 1928, gas mask filters were made from November 1940 to June 1941; this was the only product in which any mineral type of asbestos other than Quebec chrysotile was used. Paybooks had been kept since the factory was established. These were reviewed with a current employee who had been night foreman on the gas mask filter production. One carding machine was run continuously for three 8-hr shifts for the 7-month period. Only those persons whom the foreman definitely remembered working on the gas mask filters were listed—32 in all. Some may have been

TABLE 1
PERSONS IDENTIFIED AND RESULTS OF TRACING

	Filter pad manufacture								
	Montreal		Asbestos, Quebec		Gas mask assembly, Ottawa		All		
	M	F	M	F	M	F	M	F	Total
Persons identified	19	13	47	66	43	11	109	90	199
Untraced	4	5	0	1	12	1	16	7	23
Total									
Alive	4	6	26	59	20	5	50	70	120
Dead									
With death certificate	8	2	21	6	11	5	40	13	53
Without certificate									
Cause known	3[a]						3		3[a]

[a] Accidental deaths for which death certificates could not be found.

forgotten, especially those working on a day shift, and others although not actually working with crocidolite were probably exposed to it. Nine of 32 could not be traced, 10 were alive, and 13 had died.

Death certificates were sought for all 56 persons reported to have died and were obtained for 53 (Table 1). The remaining three were reported by at least two persons to have died accidentally (two in road accidents and one by drowning) but the dates were not known and the death certificates could not be found.

FINDINGS

The 53 certified causes of death are shown in Table 2. Of the total of 56 deaths, 23 were from malignant disease including 9 from mesothelioma and 8 from lung cancer. Autopsy reports in one case of lung cancer and one of generalized carcinomatosis (footnotes *b* and *c* in Table 2) revealed that both had been diagnosed postmortem as peritoneal mesotheliomas. Enquiries were addressed to pathologists about five other cases of malignant disease. In two, one of lung cancer and another of carcinoma of pancreas, the certified cause was confirmed but in three (footnotes *a*, *d*, and *e* in Table 2) the diagnosis of malignant mesothelioma was preferred by the pathologist to the one recorded on the death certificate. Thus, in 9 (16%) of the 56 deaths, malignant mesothelioma was the probable cause of death. The intervals between working with gas mask filters and death in these 9 cases lay between 24 years from last exposure and 36 years from first exposure (Fig. 1). Six of the 9 cases involved the peritoneum.

Two additional cases of pleural mesothelioma were reported in a continuing national survey of mesothelioma in Canada (McDonald and McDonald, 1977) in men who had worked at the Montreal factory. One man who had worked there from 1928 until his retirement in 1974 died in 1975. The other, who had worked there only from December 1940 until April 1941, died in 1970. Thus both men worked in the factory at the time that crocidolite was in use and their dates of

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TABLE 2
CERTIFIED CAUSE OF DEATH AND DIAGNOSIS OF MESOTHELIOMA

Cause of death	Montreal	Asbestos	Ottawa
Malignant disease	8	7	7
Cancer of lung or bronchus	4	2[a]	2
Mesothelioma—pleura		1	1
Mesothelioma—peritoneum	1	1	
Gastro-intestinal tract	2[b]		1[c]
Pancreas		1	
Breast	1		2
Brain			1
Reticulosarcoma		1	
Generalized carcinomatosis		1[d]	1[e]
Tuberculosis		3	
Pneumoconiosis			
Asbestos	2		
Silicosis (including silicotuberculosis)		2	
Heart disease		10	5
Accident		3	
Other causes		2	3
Total	10	27	16

[a] One of these two cases considered by pathologist to be a peritoneal mesothelioma.
[b] In one of these cases a peritoneal mesothelioma was diagnosed at autopsy.
[c] Peritoneal mesothelioma diagnosed at autopsy.
[d] Reviewed by pathologist who diagnosed peritoneal mesothelioma.
[e] Reviewed by pathologist who diagnosed peritoneal mesothelioma.

death were compatible with exposure in 1941 but neither had been included among the 32 names supplied by the night foreman.

Pneumoconiosis was the certified cause of death in four long-term employees. Two cases of asbestosis were recorded at the Montreal factory and one of silicosis and one of silicotuberculosis at the Asbestos factory. In seven of the nine cases of mesothelioma the total duration of asbestos exposure was short. All four cases in Asbestos worked only in the factory and never worked in the mines or mills. Three were employed only during the time crocidolite was used, for 4 months, 6 months, and 2 years respectively. The fourth worked for a total of 6 years including the 2 years when crocidolite was used. In Ottawa two cases worked for less than 2 years and the scientific officer was exposed for less than 3 years.

DISCUSSION

The mortality findings in the gas mask workers are compared in Table 3 with those in the cohort of chrysotile miners and millers described above. Comparisons of proportional mortality especially for malignant disease must be made with caution because they may be biased by differences in age, in other causes of death, and in length of observation. As relatively few of the gas mask workers have yet died the already high proportion of deaths from lung cancer and mesothelioma may in time increase further. Mesothelioma was some 60 times

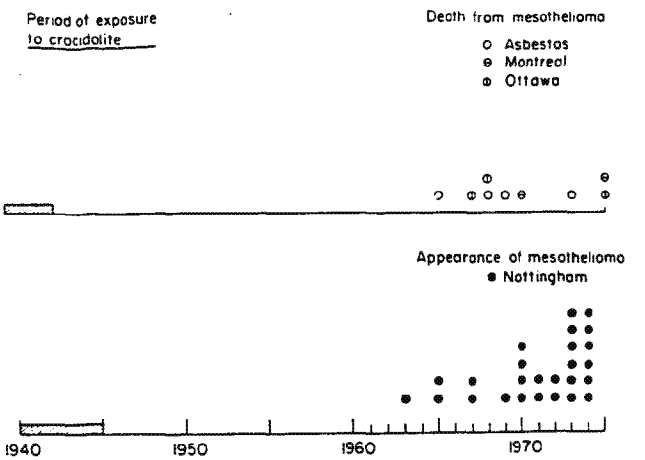


FIG. 1. Period of exposure to crocidolite and year of occurrence of mesothelioma in Nottingham, England (Jones *et al.*, 1976), and in Canada.

more frequent in the crocidolite than in the chrysotile cohort and lung cancer over twice as frequent. The proportion of deaths from other malignant diseases was similar in the two cohorts. There was a major difference in the site of the mesothelial tumours; in the crocidolite cohort 6 of the 9 cases involved the peritoneum compared with only 1 of the 11 in the chrysotile cohort. A high proportion of peritoneal tumours is characteristic of populations with a high incidence of mesothelioma (Selikoff and Hammond, 1975; Newhouse and Berry, 1976).

The proportional mortality from mesothelioma in Ottawa was 20%, in Montreal 20%, and in Asbestos 15%—remarkably similar, though, of course the numbers are small. However, only the Ottawa workers were exposed solely to crocidolite. Some of the employees in the Montreal factory had had long and probably heavy exposure to chrysotile and those in Asbestos to chrysotile and possibly other

TABLE 3
MALIGNANT DISEASE IN CHRYSOTILE MINERS AND MILLERS AND IN CROCIDOLITE GAS MASK FILTER WORKERS TO THE END OF 1975

	Crocidolite gas mask filter workers	Chrysotile miners and millers
Total cohort	199 (55% male)	11,379 (96% male)
Traced	174	10,259
Dead	56	4,247(since 1935)
Cancer of the lung or bronchus	7 (13%)	242 (6%)
Mesothelioma	9 (16%)[a,c]	11 (0.26%)[b,c]
Other malignant disease	7 (13%)	632 (14%)

[a] Four certified: two diagnosed at autopsy; three after pathologist's review.
[b] Eight certified, one of which was not thought by the pathologist to be a mesothelioma: three diagnosed at autopsy.
[c] Two cases were common to both series *a* and *b* above.

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noxious dusts. The four deaths from pneumoconiosis in these factories is evidence of this.

The most obvious explanation of the striking difference in mortality from mesothelioma between the miners and millers and the gas mask workers is asbestos fibre-type. In 1960, Wagner had reported an epidemic of mesothelioma around South African crocidolite mines (Wagner *et al.*, 1960); Newhouse and Berry (1976) have found a high proportional mortality from mesothelioma in a factory using crocidolite in addition to chrysotile and amosite. Two recent reports support the view that crocidolite carries a high risk and chrysotile a low one. First, the report on gas mask production in England by Jones *et al.* (1976) of 26 deaths from mesothelioma in a cohort of some 1600 persons. The intervals between first and last exposure and appearance of the tumours were 20 and 35 years—very similar to 24 and 36 years observed in Canada (Fig. 1). In Canada 6 of the 9 gas mask cases were peritoneal compared with 6 of 26 cases in England, but the tracing of this series was incomplete. Second, the finding by Rubino *et al.* (1977) of one case mesothelioma (0.3%) among 336 deaths in a cohort of 1252 chrysotile miners in Northern Italy parallels Quebec experience.

Another explanation of the difference may be related to the nature of the industrial process rather than fibre type. Fibre concentration and size distributions may differ in factories compared with mines and mills. Study of workers exposed only to chrysotile in manufacturing is needed to resolve this issue.

Although information on exposure levels is lacking, mesothelioma clearly occurred after very short total exposures to asbestos—not more than 3 years in 6 of the 9 cases and only 4 and 6 months in two cases. In view of this and the weight of other evidence (McDonald and McDonald, 1977) the continued use of crocidolite would appear difficult to justify except under the strictest possible control.

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