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AIRBORNE ASBESTOS IN THE VICINITY OF A FREEWAY

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Abstract—Asbestos fibres taken from fresh or worn brake linings or collected from the atmosphere near a freeway were examined by electron microscopy and electron diffraction. The major effect of braking appears to be in separating bunches of fibres and reducing their average length but not in altering their crystal structure. The suggestion that gross changes in the crystal structure are brought about by heat generated during braking is not supported by this work. Airborne samples were collected at points where there was considerable braking and where there was only slight braking. At the point where slight braking took place the airborne concentration was very low and could not be satisfactorily measured. At the point where considerable braking occurred an estimate of 5×10^3 m^{-3} particles was determined, each particle consisting of a small bundle of fibres. The majority of particles had a maximum linear dimension ≤ 2 μm.

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INTRODUCTION

The concentration of asbestos fibres in the atmosphere may reach high levels in the immediate vicinity of mining the asbestos mineral or manufacturing asbestos products. It has been known for a long time that the inhalation of fibres at these concentrations is injurious to both man and animals (Merewether, 1930). A qualitative standard which has been proposed by the E.P.A. (*News Focus*, 1973) is that there should be no visible emissions during the handling and manufacture of asbestos products. One criterion for a recommended quantitative standard is that the concentration should not exceed 5×10^6 fibres m^{-3} of length ≤ 5 μm for a 30 y exposure and that this standard should become more rigorous after July 1976 becoming 2×10^6 fibres m^{-3} (NIOSH, 1972; U.S. Dept. Labor, 1972). British and West German proposals agree with the more rigorous standard suggested above (Schutz and Woitowitz, 1973). Extensive work has been carried out on the health of workers exposed in the industries producing airborne asbestos. Much less work has been carried out on the presence of asbestos in the atmosphere far away from any such industry. Asbestos was found in all samples taken from the atmosphere of several cities in Europe which did have an asbestos industry (Holt and Young, 1973). The asbestos was present chiefly as single fibres but a small fraction occurred as agglomerates. No quantitative estimate of concentration was made but compared to other suspended particulates it was small. Preliminary results for New York city showed concentrations ranging from 11 to 60 ng m^{-3} with duplicate samples differing by a factor of 2-3 (Selikoff, 1972; Nicholson *et al.*, 1973). Asbestos was also found to be present in all 200 samples taken from the atmosphere of 49 cities in the U.S.A. (Selikoff, 1972).

The source of asbestos emissions in the absence of asbestos mining and industry is a matter of speculation but one strong possibility is from the brake linings of automobiles. These linings are subjected to considerable wear leading to the release of asbestos dust. In one careful study the release of asbestos was measured by surrounding the brake drum with a collector and capturing the total emission (Jacko *et al.*, 1973). A total emission of 17.8 μg km^{-1} for passenger vehicles and 54.8 μg km^{-1} travelled for light trucks were quoted as typical values. Not all this emission reached the atmosphere, some depositing upon the ground and some being retained by the brake drum. The fraction which became airborne was estimated to be 3.7% for passenger vehicles and 2.9% for trucks. This research also gave the expected result that heavy braking produced more emission than light braking. Although it is very difficult to convert these results into atmospheric concentrations clearly only very low concentrations would be anticipated.

Lynch (1968) examined the dust from brake linings and from the appearance of the fibres suggested that the crystal structure of the fibre was degraded by heat released during braking. Holt and Young (1973) found that fibres collected by them from the atmosphere showed very little evidence of loss of crystallinity, and, therefore, following Lynch's suggestion, concluded that building materials were a more likely source than brake linings.

The aim of the work reported here was to examine more closely the possible contribution that brake linings could make to the asbestos concentration in the atmosphere.

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EXPERIMENTAL

A number of methods have been proposed for the estimation of asbestos particles in the atmosphere (Keenan and Kupel, 1968; Lane *et al.*, 1968; Gadsden *et al.*, 1970) but at the present time the only method of sufficient sensitivity and selectivity for the very low concentrations involved is the electron microscopy of samples collected on suitable filters. Atmospheric samples were collected on a Millipore filter (VSWP 047, 0.025 μm pore dia.) at an average flow rate of 0.6 l min^{-1}. A High-Volume sampler was modified by placing an aluminium face-plate containing a small tube over the inlet to the sampler. A Millipore filter holder was connected by a plastic tube with a rotameter interposed to the small tube on the face plate. Samples were taken at three locations, (i) on the roof of the Department of Industrial Science, University of Melbourne, 10 m above street level and 30 m from the nearest traffic, (ii) outside the same building 0.8 m above street level, (iii) at the exit of the S.E. end of the Tullamarine freeway, 0.8 m above ground level. This last sampling point was 50 m from the position where brakes were applied to reduce the speed of vehicles from approx. 100 to 60 km h^{-1}. The total number of vehicles passing all three locations during the total sampling period was very similar and the major difference was the absence, locations (i and ii), or presence, Location (iii), of extensive braking. The sampling period was from 08.00 17:00 h during November 1973; the weather was fine with only light winds over this period. After the samples had been collected the Millipore filters were coated with a carbon film, approx. 20 nm thickness, and then five small pieces (1.5 × 1.5 mm) cut out at random. Each small section was placed on a copper grid, carbon film facing down, and the membrane material removed by dissolution in acetone. Electron micrographs and diffraction patterns were obtained from these specimens using a Phillips EM 200 microscope at 80 kV. The electron diffraction patterns were calibrated by evaporating aluminium on to the copper grid and by comparison interplanar spacings, $d(hkl)$, could be determined. Samples of fresh and worn brake drum linings were obtained from an automobile repair shop and were crushed gently in a mortar and pestle with a few ml of chloroform. An electron microscope grid covered with a smooth film of evaporated carbon was then dipped into this suspension and the chloroform allowed to evaporate.

RESULTS AND DISCUSSION

Figures 1 and 2 show electron micrographs and diffraction patterns from a sample prepared from a fresh brake lining. The characteristic structure of chrysotile asbestos, long filaments each of which is a hollow cylinder (McCrone and Delly, 1973), is clearly visible in this micrograph. The electron diffraction patterns of chrysotile have been determined and indexed by Yada (1967, 1971). In Table 1 the interplanar spacings determined from the pattern of fresh brake linings are compared to Yada's values and the agreement is seen to be excellent.

Figures 3 and 4 show results for the dust from worn brake linings. The average length appears to be shorter than in the fresh lining but the hollow cylindrical structure is still obvious. The diffraction pattern still consists of well-defined rings and the interplanar spacings derived from these rings are in good agreement with Yada's values (see Table 1). There was no indication from the diffraction pattern of the presence of forsterite, the name given to thermally-degraded asbestos. It appears that for the wear this lining had received no significant changes in the crystal structure due to excessive heating had taken place. Temperatures within brake drums may reach 873 K under racing conditions with severe and repeated braking

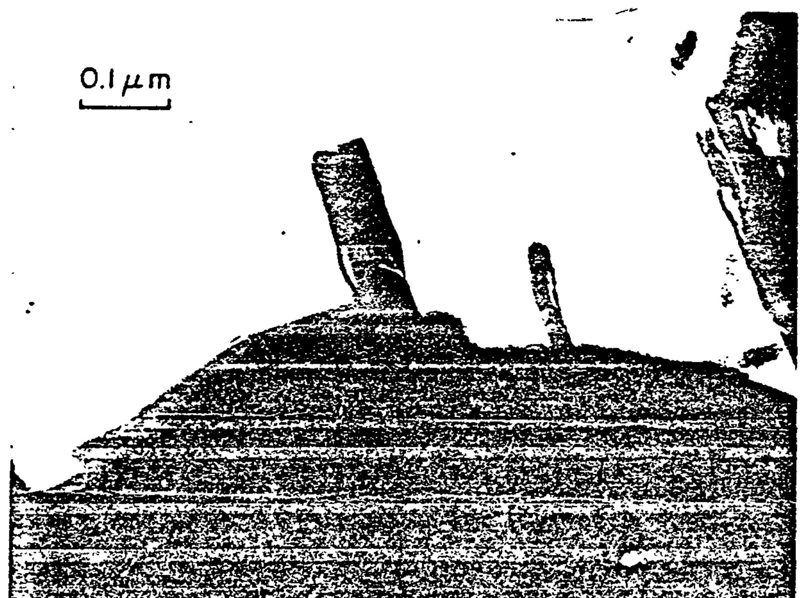

Fig. 1. Dust sample from crushed new brake linings.

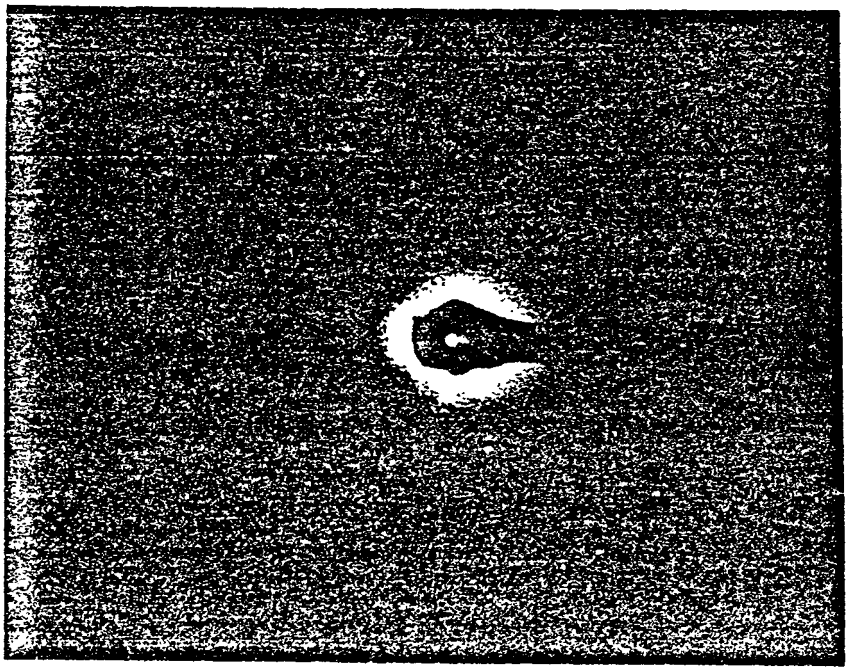

Fig. 2. Diffraction pattern from sample in Fig. 1.

but would be expected to be very much lower under normal city driving. Chrysotile has been shown to maintain its crystal structure until temperatures in excess of 800 K are reached (Yada, 1971; Robock and Klosterkotter, 1973). The observations on the worn brake drums are then consistent with the likely temperatures reached and the known thermal behaviour of chrysotile. Yada (1967, 1971) has shown that electron bombardment inside the electron microscope can lead to production of amorphous material in the fibres and, therefore, excessive exposure during examination should be avoided.

Table 1. Values of $d(hkl)$ for chrysotile and brake linings, nm $\times 10^{-1}$

Values for chrysotile (Yada, 1967, 1971)	Fresh brake lining	Worn brake lining	Plane (hkl)
7.30	7.30	7.21	(001)
4.60		4.60	(110)
4.50	4.48		(020)
3.65	3.62	3.67	(002)
2.70		2.67	(200)
2.60	2.62		(130)
2.51	2.52	2.56	(201)
2.43	2.45	2.47	(003)
2.30			(220)
2.25	2.24	2.26	(040)
2.15	2.13	2.10	(202)
1.82			(004)
1.80	1.79	1.75	(050)
1.53	1.54	1.55	(330)
1.46			(005)
1.35	1.32	1.33	(400)
1.21	1.21	1.19	(060)

Samples taken either on the roof or at ground level near the Department of Industrial Science contained very low concentrations of asbestos fibres (Fig. 5). Although the rings in the diffraction pattern (Fig. 6) are more diffuse than from fresh linings the interplanar spacings shown in Table 2, again match both the values for fresh linings and Yada's values. Although the comparison in Table 2 enabled the presence of asbestos to be deduced, no attempt was made to estimate the atmospheric concentration because of its very low value.

Samples taken at the exit from the freeway, however, contained a much higher concentration of asbestos particles (Figs. 7 and 8) estimated at an average of 5×10^5 particles m^{-3} over the 9 h sampling period. The general appearance of the fibre clusters and the presence of other material is very similar to that observed for the worn brake lining dust. Again the diffraction patterns do not show significant amounts of amorphous material and match Yada's values (Table 2).

Table 2. Values of $d(hkl)$ for chrysotile and airborne asbestos nm $\times 10^{-1}$

Values for chrysotile (Yada, 1967, 1971) (hkl)	Dept Industrial Science	Tullamarine freeway exit
3.65 (002)	3.65	3.60
2.15 (202)	2.20	2.15
1.80 (050)	1.80	1.75
1.21 (060)	1.28	1.18

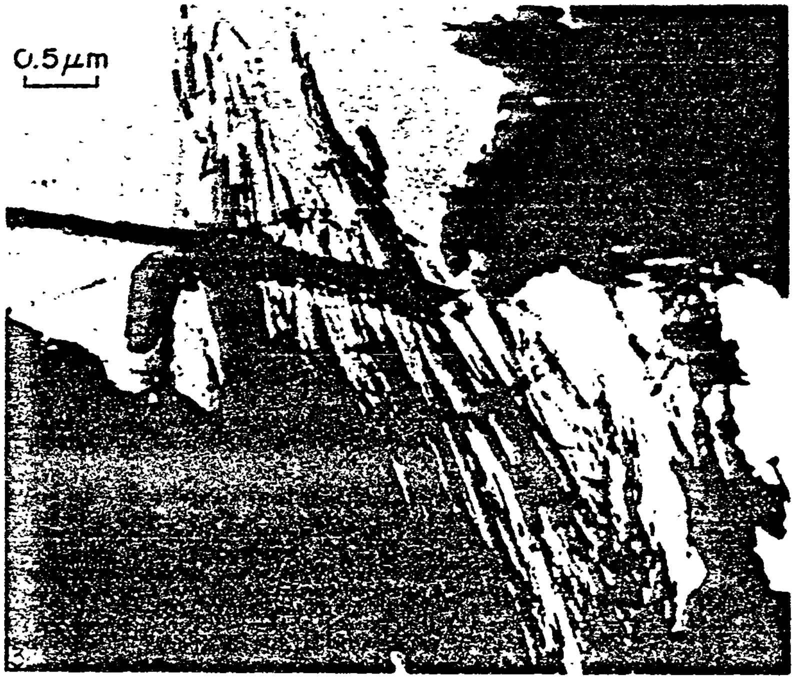

Fig. 3. Dust sample from worn brake lining.

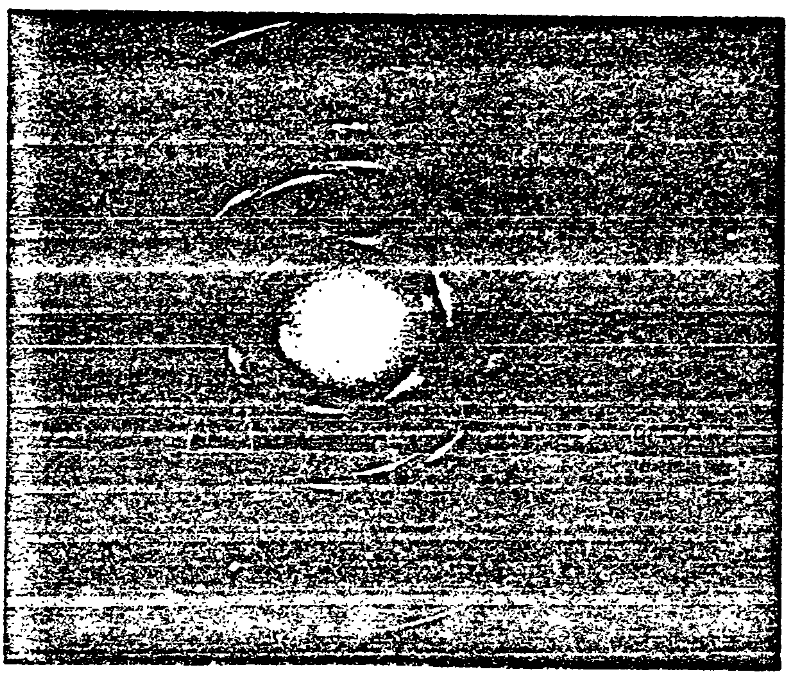

Fig. 4. Diffraction pattern from sample in Fig. 3.

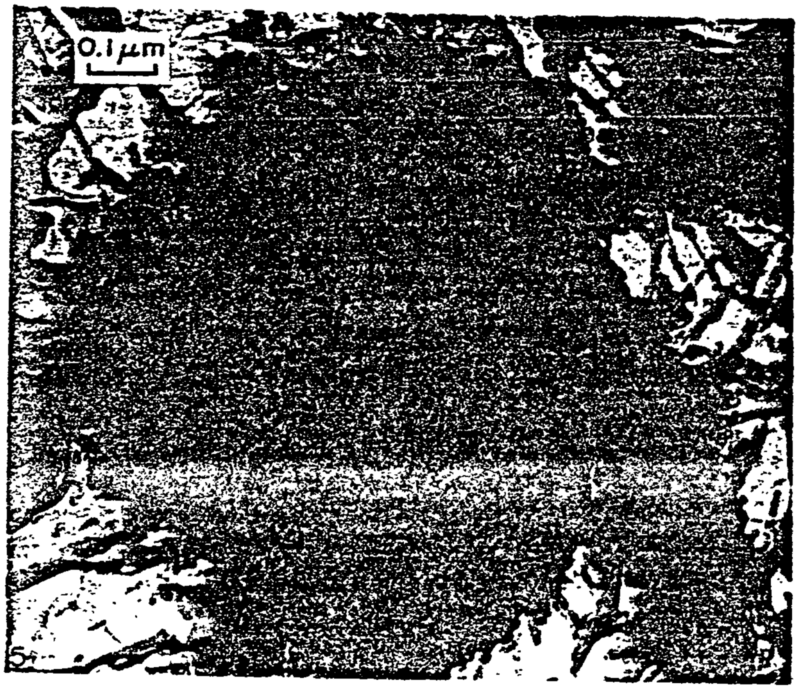

Fig. 5. Atmospheric sample collected 0.8 m above ground level at Melbourne University.

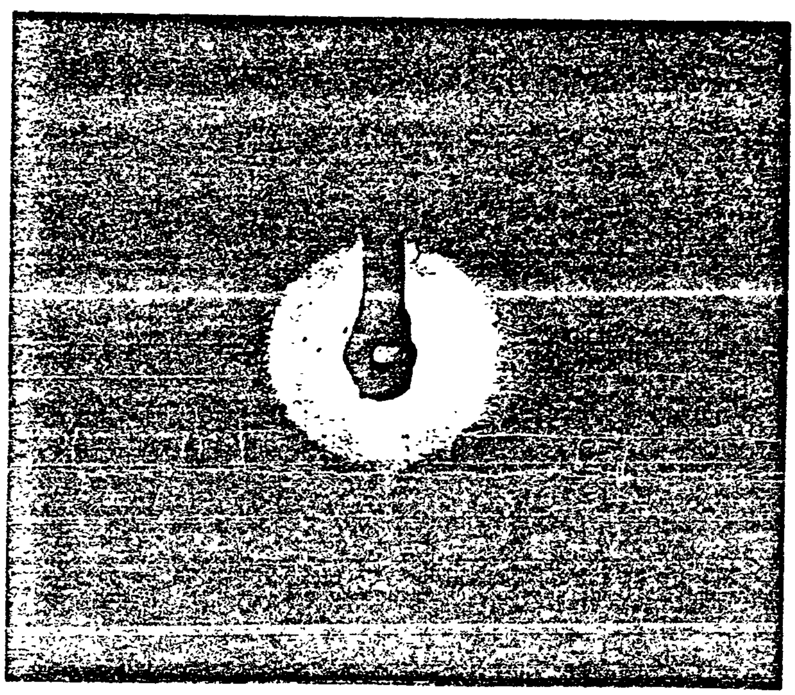

Fig. 6. Diffraction pattern from sample in Fig. 5.

Fig. 7. Atmospheric sample collected 0.8 m above ground level at the exit of Tullamarine Freeway.

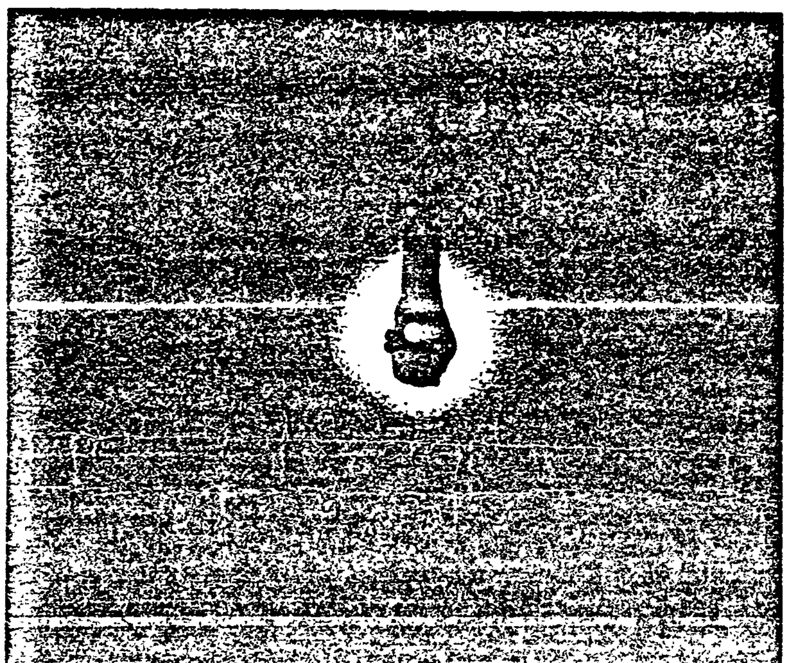

Fig. 8. Diffraction pattern from sample in Fig. 7.

The particles consisted of small bundles of fibres together with other material which may have contained binder present in brake linings. Another possible source for this amorphous material consistent with a location where braking occurred is wear from tyres. Measurements by other workers (Pierson and Brachaczk, 1975) have shown concentrations of airborne debris from tyre wear from 0.05 to 2.2 $\mu g\ m^{-3}$. The number of fibres in the bundle and their size varied considerably and no attempt was made to count individual number of fibres. The majority of bundles did have a maximum dimension $\leqslant 2\ \mu m$. Although these results are limited and of a preliminary nature the following points can be made:

(i) Electron diffraction has proved to be a method of great sensitivity in the identification of asbestos particles suitable for the low concentrations found in atmospheric samples.

(ii) Asbestos fibres from brake linings operated under normal conditions have the same crystal structure as asbestos from other sources. The absence of thermally-degraded material cannot, therefore, be taken as evidence that brakes have not contributed to a particular sample.

(iii) The results from the samples collected at the freeway exit suggest that emissions from brakes can become airborne. The concentrations reached are very low, below the recommended exposure standard (NIOSH, 1972; U.S. Dept. Labor, 1972), and consistent with the prediction by other workers that only a small fraction of the total dust formed becomes airborne (Jacko, *et al.*, 1973).

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