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Asbestos Exposure of Brake Repair Workers in the United States*†

WILLIAM V. LORIMER, M.D., ARTHUR N. ROHL, PH.D., ALBERT MILLER, M.D., WILLIAM J. NICHOLSON, PH.D., AND IRVING J. SELIKOFF, M.D.

Introduction

At least 900,000 people in the United States are employed as auto mechanics or garage workers (1). An unknown but large percentage of these workers regularly service brake linings. Brake linings pose a potential hazard for asbestos exposure because they contain 33–73% asbestos (2–4). Jacko and Ducharme (2) have estimated that 70 million pounds of asbestos (32 million Kg) are worn away from brake linings each year in the United States. Much of the asbestos worn away (around 80%–90%) drops to the road or is emitted into the atmosphere.

The wearing of asbestos linings is complex and for brief periods of time local areas in the lining surface have temperatures exceeding 630°C, the temperature at which chrysotile asbestos loses the major portion of its water of hydroxylation and loses its characteristic morphology. The bulk temperature cannot exceed 350–400°C for any length of time without decomposition of the organic polymer binder material.

Several investigators (2–4) have analyzed bulk brake-drum dust for chrysotile and have found weight percentages of between 0.3% (2) to "at most 1%" (3). Lynch (4) reported percentages of 10% and 15% free fiber in two of fifteen samples. Most of the rest were below 1%.

Personal and background sampling of workers engaged in brake maintenance work at the job site gives a more direct estimate of exposure.

During brake-lining servicing the wheel is removed and all loose dust is removed from the drums and backplates. Compressed air jets are usually used (Fig. 1). In a two-city survey in the USA, Castleman et al (5) found that 175 out of 220 establishments used this procedure. Alternates include vacuuming and wet brushing. The brake lining itself may require grinding to remove irregularities or removal and replacement. The new lining may require considerable manipulation to fit the brake shoe—beveling edges and punching holes in the material, for example. As an alternative, the brake shoe and lining

From the Department of Community Medicine and the Department of Medicine, Mount Sinai School of Medicine of The City University of New York, N. Y. 10029.

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Requests for reprints should be sent to: Dr. William Lorimer, Environmental Sciences Laboratory, Mount Sinai School of Medicine of The City University of New York, N. Y. 10029.

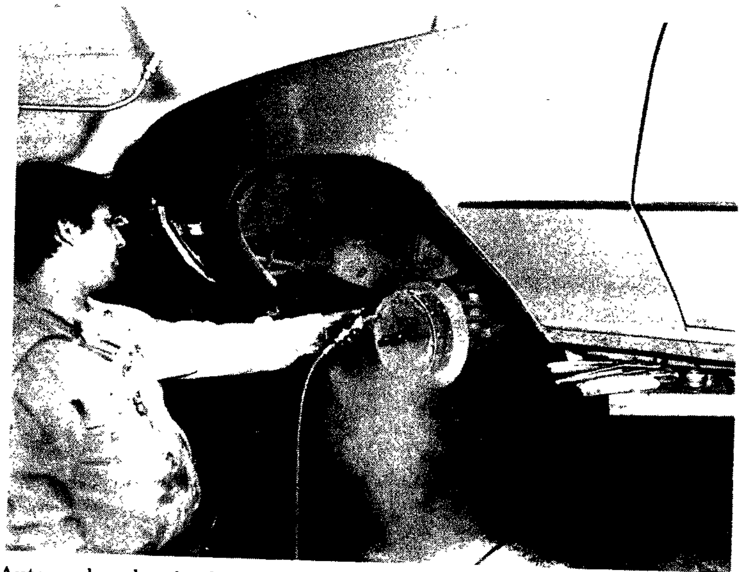

FIG. 1. Auto worker cleaning brake drum with compressed air jet. Note personal sampler on the right side of worker's chest.

may be replaced as a unit. A number of studies have measured exposure in such work, and fiber counts reported are summarized in Table I.

In addition, Boillat and Lob (8) reported values for various manipulations of the brake-lining material including punching holes for rivets, and grinding. Sampling interval is not given. Fiber counts ranged from 0.3 to 29.2 fibers/ml; four of the nine values were over 5 fibers/ml (5,000,000/m^3).

Asbestos disease: Asbestosis in brake liners has been recognized and compensated in Great Britain for many years (9), and instances of mesothelioma in garage workers have also been identified (10–12). Boillat and Lob (8) examined 39 vehicular maintenance workers who had performed brake-lining service for about ½–2 hours a day for a mean of 8± years. They found two men who may have had mild cases of asbestosis. The study. however, provided no information as to the risk with longer exposures.

Present Investigation

In order to provide additional information on this subject, we have investigated asbestos exposure among brake repair maintenance workers in New York City and have initiated a clinical survey of workers employed in the workshops studied.

ASBESTOS EXPOSURE

Materials and methods

Personal air samples were taken during brake-lining maintenance work both on automobiles and trucks. These were peak samples taken over 2–10 minutes

TABLE I

TABLE I

Asbestos Fiber Measurements in Brake Maintenance Service

Reference	Operation	Sampling method	Sampling interval (min)	Fibers/ml[3]	Peak or TWA*	Comments
Hickish and Knight (3)	blowing out dust	static samples by side of car-2	90	1.25	TWA*	Four brake blowouts during this time
		static samples, in dust cloud during blowing-2	90	2.55		
	mechanic employed on brake cleaning, blowing	personal sampling (2 men)	450	0.68	TWA	—Eight hour shift
			100	7.09		—Work on brakes
			300	0.08		—Not working on brakes
	background	pairs of static samples (morning and afternoon)	180	0.28	TWA	Brakes blown in morning but not in afternoon
	—adjacent bay		180	0.07		
	—2 bays away		180	0.17		
			180	0.07		
	—garage center		180	0.49		
			180	0.11		
Hatch (6)	blowing out dust	peak samples over a few secs. 7 samples from dust clouds	few seconds	43 ± 2.1	Peak	Hand-held pump
Knight and Hickish (7)	blowing dust	personal (two men)	60	5.35		Taken over hour during which brake work done
				0.84		
		from breathing zones (2 men)	2 secs.	87	Peak	pump in breathing zone
				87		
		static sampler adjacent bay	60	0.52		
				0.16		

* TWA = Time weighted average

during which the workers were performing certain tasks, such as blowing dust from drum brakes, renewing used linings by grinding, and beveling new linings. Background samples were also taken at varying distances and times. The standard techniques for filter processing and fiber counting which have been adopted by the Occupational Safety and Health Administration of the US Department of Labor were used (13). Samples of dust collected in the standard manner were examined both by standard optical techniques (fibers/ml > 5μ) and by electron microscopy to give $\mu g/m^3$ of air, and the results compared. Bulk samples of brake-drum dust were collected and analyzed by electron microscopy. One hundred fibers were sized in each sample. Qualitative morphologic comparisons of the fibers with standard chrysotile morphology were made.

Results

Fiber concentrations for personal and background samples during blowing dust from drum brakes on automobiles are presented in Table II. The values show extensive variation, but the values at 3–5 feet are by far the highest, with a mean of 15.9 fibers/ml.

Fiber concentrations for personal and background samples during renewing used linings by grinding truck brakes are presented in Table III. The mean concentration for the personal sampler was 3.8 fibers/ml. Fiber concentrations

TABLE II

Personal Samples—Automobile Brake Service

Operation	Distance	Concentration (fibers/ml)*
Blowing dust out of drum brakes	3–5 ft.	13.8
Blowing dust out of drum brakes	3–5 ft.	29.4
Blowing dust out of drum brakes	3–5 ft.	6.6
Blowing dust out of drum brakes	3–5 ft.	13.6
Blowing dust out of drum brakes	5–10	3.8
Blowing dust out of drum brakes	5–10	2.0
Blowing dust out of drum brakes	5–10	4.2
Blowing dust out of drum brakes	10–20 ft.	0.4
Blowing dust out of drum brakes	10–20 ft.	4.8

Background Samples—Automobile Brake Service

	Distance from Operation	Time Lapse	Concentration (fibers/ml)
Blowing dust out of drum brakes	10 ft.	0 min.	0.3
Blowing dust out of drum brakes	20 ft.	0 min.	0.8
Blowing dust out of drum brakes	12 ft.	5 min.	0.2
Blowing dust out of drum brakes	50 ft.	5 min.	0.1
Blowing dust out of drum brakes	65 ft.	7 min.	0.1
Blowing dust out of drum brakes	75 ft.	14 min.	0.1

* Only fibers longer than 5 μ were counted by phase microscopy at 400×.

TABLE III

Personal Samples—Truck Brake Service

Operation	Concentration (fibers/ml)
Renewing used linings by grinding	2.7
Renewing used linings by grinding	7.0
Renewing used linings by grinding	2.2
Renewing used linings by grinding	4.1
Renewing used linings by grinding	5.0
Renewing used linings by grinding	4.7
Renewing used linings by grinding	5.6
Renewing used linings by grinding	1.7
Renewing used linings by grinding	2.5
Renewing used linings by grinding	2.0

Background Samples—Truck Brake Service

Operation	Distance	Concentration (fibers/ml)
Background to grinding used linings	10 ft.	1.2
Background to grinding used linings	10 ft.	1.7
Background to grinding used linings	25 ft.	1.0
Background to grinding used linings	25 ft.	0.6
Background to grinding used linings	60 ft.	0.2

for personal and background samples during beveling new linings for trucks are given in Table IV. The mean concentrations were 37.5 fibers/ml.

To determine the correlation between optical fiber counts and mass of chrysotile, sections of filters collected as above were analyzed both by phase contrast optical microscopy and transmission electron microscopy. The results are given in Table V. Ten samples of bulk brake-drum dust were analyzed to determine the percentage of short fibrils, defined as 250–500 Å × 750–3750 Å. A mean of 83% of all chrysotile fibers were in this category. A mean of about 20% of the total mass of the ten samples was chrysotile by electron diffraction. Throughout the examination by electron microscopy, attention was given to the morphology of the fibers. A majority of fibers showed little alteration in the typical chrysotile fiber (see Figure 2). Some fibrous and granular particles, when analyzed by electron microscope-electron microprobe techniques, had structural and chemical characteristics of fosterite, a thermal alteration product of chrysotile (Fig. 3). Amorphous material with magnesium silicate composition was also found along with the fibrous particles (Fig. 4).

CLINICAL STUDY

Materials and methods

104 men, members of a union of vehicular maintenance workers, were examined in a preliminary study of brake-maintenance workers in New York City. All were volunteers. The examination included a detailed occupational and environmental history, medical history, physical examination, chest

TABLE IV

Personal Samples—Truck Brake Service

Operation	Concentration (fibers/ml)
Beveling new linings	31.7
Beveling new linings	23.7
Beveling new linings	32.7
Beveling new linings	72.0
Beveling new linings	26.3

Background Samples—Truck Brake Service

Operation	Distance	Concentration (fibers/ml)
Background to beveling linings	8 ft.	0.6
Background to beveling linings	12 ft.	0.5
Background to beveling linings	12 ft.	0.3
Background to beveling linings	30 ft.	0.3

TABLE V

Automobile Brake-Lining Service

Operation	Comparison of Optical and E. M. Fiber Counts	
	Optical Microscopy	Electron Microscopy
	(fibers/ml)	*μg/m³*
Light grinding of new linings before installation	4.8	53.0
Grinding new linings before installation	2.7	66.0
Blowing dust off drum with air jet	0.4	1.1
Cleaning brake drum with hand brush	3.6	6.5
Background to blowing out brake drum (10 feet away)	0.3	0.2
Background to blowing out brake drum (20 feet away)	0.8	0.1
Background to blowing out brake drum (65 feet away)	.1	0.2

x-ray, and pulmonary studies. Three men were excluded from analysis because they had worked in a shop for less than 10 years. Also excluded from analysis were nine men whose occupational history raised the possibility of other asbestos exposure. Two men were excluded because of known chest disease. The remaining 90 believed themselves to be healthy; all either were currently working (84) or had retired because of age (6).

Occupational Categories

General mechanics	67
Body workers	7
Undercoaters	5
Lubrication	4
Painters	2
Miscellaneous: other crafts	5
	90

FIG. 2. Chrysotile fibers from brake-drum dust.

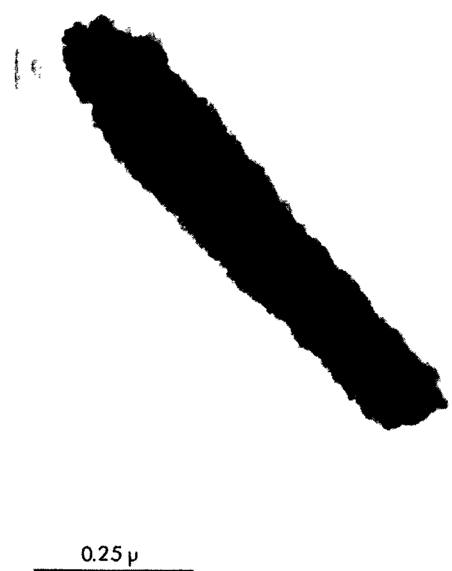

FIG. 3. A fosterite fiber from brake-drum dust.

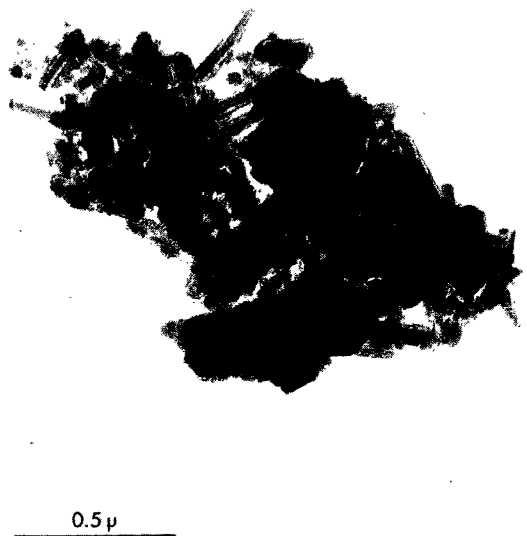

FIG. 4. Amorphous material mixed with chrysotile fibers from brake-drum dust.

Sixty-one of the sixty-seven general mechanics did brake lining more than once a week for ten years or more. The workers had a mean age of 48 ± 12 years with 28 ± 8 years on the job.

Results

Clinical examination: Findings on pulmonary examination were minimal. There were five cases of clubbing and four instances in which fine rales were heard.

Pulmonary function: Standard spirometry was performed on a Systems Research Laboratory screener. The measurements used were FVC/VC predicted, FEV_1/FVC, and, as a more sensitive measure of obstruction in small airways, the FEF_{25}/FVC ratio (FEF_{25} is the forced expiratory flow rate with 25% of the vital capacity remaining to be expired). The results were classified into either restrictive, obstructive, combined, or normal according to the schema given in Table VI; the results are detailed in Table VII. 29% had decreased vital capacity, the percentage increasing with age and most markedly after 20 years from onset on auto work (Table VIII). The differences are statistically significant $.05 > p > .02$.

Effect of smoking: Significantly more smokers and ex-smokers than non-smokers were obstructed (Table IX $X^2 = 8.48$ $.01 > p > .001$). (See note at end of the Table.) There was no significant difference, however, among smokers, non-smokers, and ex-smokers with respect to restriction ($X^2 = .01$, not significant).

TABLE VI

Classification of Pulmonary Function in Vehicular Maintenance Workers

	$FEV_1/FVC \geq .75$		$.59 < FEV_1/FVC < .75$*	$.59 \geq FEV_1/FVC$*
	$FEF_{25}/FVC \geq .30$	$FEF_{25}/FVC < .30$		
FVC/VC pred $\geq .80$	Normal	Obstructive	Obstructive	Obstructive
FVC/VC pred = .70–.79	Restrictive	Combined	Combined	Obstructive
FVC/VC pred $\leq .69$	Restrictive	Combined	Combined	Combined

* Note: all those with $FEV_1/FVC < .75$ also had $FEF_{25}/FVC < .30$

TABLE VII

Pulmonary Function Abnormalities in 87 Vehicular Maintenance Workers with over 10 Years Experience

	Number	Percent
Restrictive	14	16%
Obstructive	32	37%
Combined	11	13%
Any abnormalities	57	66%

TABLE VIII

Restriction of Pulmonary Function by Year of Onset of Work in 90 Vehicular Maintenance Workers

	Abnormal					
Total restrictive and combined	1956–65		1946–55		Before 1946	
	Yes	No	Yes	No	Yes	No
25	1 (6%)	15	14 (33%)	28	10 (34%)	19

For before 1956 compared with 1956 and after: $X^2 = 4.84$ $.05 > p > .02$

TABLE IX

Relationship between Obstruction or Restriction and Smoking in Vehicular Maintenance Workers

	Number of Subjects	Current Smokers	Never Smoked	Ex-Smokers
Normal	31	10	13	8
Obstructive	31	15	5	11
Restrictive	14	3	6	5
Combined	11	5	1	5
Total	87	33	25	29

For restriction $X^2 = .01$ N.S. (smokers and ex-smokers compared with never smoked)
For obstruction $X^2 = 8.28$ $.01 > p > .001$
Those in the combined group counted as being both obstructive and restrictive

The relationship between pulmonary function signs of restriction and abnormal x-rays was investigated. No significant association was found (Table X).

Chest x-ray: The chest x-rays were read twice by consensus reading, using at least three experienced readers, and categorized according to the ILO/U/C classification. An x-ray was read as abnormal if fine or moderately thin, irregular linear opacities were present (s or t $\geq$ 1/0) and/or pleural thickening was present (a-1 or more). The prevalence of abnormal readings is given in Table XI. Parenchymal abnormalities were present in 19 instances, nine 1/0, six 1/1, two 1/2 and two 2/2. X-ray findings consistent with asbestosis increased with time; such a trend is evident in Table XII. This trend is statistically significant.

TABLE X

Relationship between X-Ray Reading and Pulmonary Function Tests in 87 Vehicular Maintenance Workers

Pulmonary function	Number of Subjects	X-ray reading		Percent
Restriction	25	Abnormal*	5	20%
		Normal	20	80%
Obstruction	43	Abnormal*	15	35%
		Normal	28	65%
Normal	30	Abnormal*	8	27%
		Normal	22	73%

* parenchymal fibrosis and/or pleural thickening
For overall pattern $X^2 = 1.78$ $.50 > p > .30$
For restriction alone $X^2 = 1.21$ $.30 > p > .20$
For obstruction alone $X^2 = 1.50$ $.30 > p > .20$
For obstruction and restriction compared to normal: $X^2 = .08$ $.80 > p > .70$

TABLE XI

X-Ray Changes in 90 Vehicular Maintenance Workers with over 10 Years' Experience

	Number	Percent
Parenchymal fibrosis	18	20%
Pleural thickening or calcification	5	6%
Both parenchymal and pleural changes	1	1%
Any changes	24	27%

TABLE XII

X-Ray of Vehicular Maintenance Workers by Year of Onset of Work

Abnormal*					
1956–65		1946–55		Before 1946	
Yes	No	Yes	No	Yes	No
3 (18%)	14	10 (23%)	33	14 (47%)	16

* Parenchymal fibrosis (ILO/UC s, t $\geq$ 1/0) and/or pleural thickening
X^2 for before 1956 compared with 1956 and after: $X^2 = 5.95$ $.02 > p > .01$

Discussion

The amount of asbestos brake material worn away each year is enormous, and even if only a small percentage is morphologically unaltered, then hundreds of thousands of kilograms remain. Fiber counts in various operations in brake maintenance work show wide variations. Certainly, they indicate that these operations need more systematic evaluation, both as to peak and time-weighted values. Peak values frequently exceed the 10 fiber/ml legal limit for peak values in the United States.

Much of the chrysotile is altered to other phases, which may be fibrous or granular. The biologic activity of these materials has not been studied. Detailed classification and quantification of these changes has not been reported. However, even the incomplete correlations presented above between optical fiber counts and electron microscopic volumes of morphologically intact chrysotile is evidence that fiber counts are useful measures of asbestos exposure in brake repair work.

Many of the vehicular maintenance workers examined showed signs of asbestosis. The prevalence both of chest x-ray changes and restrictive function results was significantly higher after 20 years of exposure than before, a result expected after occupational exposure to asbestos (14, 15).

Summary and Conclusion

Measurements were made by optical microscopy of asbestos levels during brake repair and maintenance work in New York City. Both time-weighted averages and peak levels showed significant asbestos exposure. Over four-fifths of the total number of chrysotile fibers in brake-drum dust were below 0.4μ in length and not visible by optical microscopy. Over one-quarter of a group of experienced vehicular maintenance workers examined had evidence of x-ray abnormalities consistent with asbestosis; one-quarter also had restrictive pulmonary function test findings. While this preliminary study was limited in scope and was restricted to volunteers, and its results cannot therefore readily be generalized to all brake maintenance workers in the United States, the findings suggest that asbestos disease will be present among such workers and that appropriate control measures should be urgently instituted.

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Email (TIFF) To: research@awpk.com

Carrie Waters
211 Centre Street
Waters and Kraus
Dallas, TX 75208

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