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Exposure to Asbestos During Brake Maintenance of Automotive Vehicles by Different Methods

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Asbestos concentrations were measured during the different operations of brake maintenance of passenger cars, trucks and buses in 24 Finnish workplaces. The estimated average asbestos exposure during the workday (8-hr time-weighted average) was 0.1-0.2 fibers/cm^3 during brake repair of trucks or buses, and under 0.05 f/cm^3 during repair of passenger car brakes when the background concentration was not included in the calculations. The background concentration was estimated to be less than 0.1 f/cm^3. During brake maintenance of buses and trucks, heavy exposure, 0.3-125 (mean 56) f/cm^3, was observed during machine grinding of new brake linings if local exhaust was not in use. Other short-term operations during which the concentration exceeded 1 f/cm^3 were the cleaning of brakes with a brush, wet cloth or compressed air jet. During brake servicing of passenger cars, the concentration of asbestos exceeded 1 f/cm^3 only during compressed air blowing without local exhaust. The different methods of decreasing the exposure and the risk of asbestos-related diseases among car mechanics are discussed.

Introduction

Brake maintenance and repair is carried out in most garages and service stations in Finland. Although substitute materials not containing asbestos are used increasingly, the brake and clutch linings of many cars, as well as the brake drum dust, still contain chrysotile asbestos. Therefore, car mechanics and other garage workers potentially are exposed to asbestos fibers emitted during brake servicing.

According to the Finnish Register of Employees Occupationally Exposed to Carcinogens,[1] about 1400 car mechanics are exposed to asbestos in Finland, most of them during brake maintenance of trucks and buses.[2] The registration, however, is based on the notifications made by the employers, and this value does not include every worker who maintains or repairs brakes. If those persons who deal with passenger car brakes or who service brakes infrequently are included also, the number of exposed workers approaches the total number of car mechanics, which is about 20 000 (nearly 1% of the employed population).

During 1977-1983, the concentrations of asbestos fibers were measured by the occupational hygienists of the Finnish Institute of Occupational Health in 24 workplaces to study the exposure of car mechanics to asbestos during different operations and brake maintenance procedures. This article is a summary of these measurements.

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Friction Materials and Brake Maintenance Procedures

Drum brake linings usually contain 30-70% (by wt.) and disc brake pads 10-30% of chrysotile asbestos. In addition to asbestos, the brake linings contain phenolic type resins, lubricants and metal oxides.[3-7] The typical composition of asbestos-free, "semi-metallic," drum brake linings or disc brake pads is as follows: metals (Fe) 60-70%; graphite 15-25%; filling agents 7-10%; and binders 0-5%.[7] Other types of asbestos-free friction materials also have been developed.

During braking, most asbestos fibers lose their fibrous character, but the brake drum dust still contains some chrysotile asbestos. Several investigators have analyzed brake drum dust and found 0.1-1 wt-%[3,8-11] or 1-15 wt-% of chrysotile fibers.[4-6,12,13] Besides drum dust, the brake repair workers may be exposed to unaltered asbestos fibers during grinding, beveling or riveting of new brake linings.

The procedure of brake maintenance depends on the type of vehicle and brakes. Trucks and buses usually have drum brakes. After removing the wheel and brake drum, the cleaning of the brakes may be carried out by blowing with a compressed air jet, by brushing, by wiping with a wet cloth, by sucking with a vacuum cleaner, or by washing with water. A vacuum funnel is commonly used during compressed air cleaning because of heavy dust emission, but it is less common during other procedures. If the brake linings are worn out, they are removed and new linings are riveted to the brake shoes. If needed, the new linings are ground to fit the shoes. Finally, the brake shoes, brake drum and the wheel are assembled.

The brakes of passenger cars are either of disc or drum type. The disc brakes gather less debris than the drum brakes

because of more open structure. The maintenance of disc brakes usually consists of the removal of old pads, cleaning of the brakes with compressed air, and attaching of new brake pads. The maintenance of drum brakes is basically similar to that of heavy vehicles.

Methods

The authors carried out measurements in 7 out of 24 workplaces under study. The other results were collected from the measurement reports that include a description of sampling and analytical methods used, remarks on the prevailing circumstances during the measurements, data on sampling sites and times, and the results with pertinent comments. The sampling procedures and the analytical methods were the same in all measurements.

Asbestos was measured in the breathing zones of car mechanics or within the working areas. Dust samples were collected on Millipore membrane filters. A sampling rate of 2 L/min and a sampling time of 1-60 min (air volume 2-120 L) was used depending on the duration of the operation and the expected dust concentration to get a proper fiber density on the filter for microscopic counting.

Asbestos fibers (length over 5 μm, diameter under 3 μm and the aspect ratio over 3:1) were counted by a phase contrast-optical microscope according to the standardized method (Finnish Standard SFS 3868).[14] A similar method is used in many countries (*e.g.*, Sweden, Norway, Denmark, Great Britain, the Federal Republic of Germany and the United States). This method has been tested in international quality control analyses.[15]

In addition, respirable dust containing asbestos was measured in some workplaces. Leitz tyndallometer (TM Digital) that measures dust with particle diameters up to 3 μm was used with xy-plotter to monitor the dust concentration by time, and for the comparison of the relative dust concentrations produced by different working procedures.

Eight-hour time-weighted average (TWA) concentrations of asbestos were estimated for different work procedures. The estimates were calculated by using the measured mean and maximum concentrations, as well as the mean durations of the operations. It was assumed that the brake maintenance of four wheels was carried out during the workday. Other less common operations — such as grinding of brake linings, turning of brake drums and clutch repair — were assumed to take 1 hr of the workday. The calculated concentrations do not include the background concentration of asbestos, because only very few data were available.

Results

The results are presented by operation and type of vehicle. As to buses and trucks, the results were similar; and they are combined in Table I. The highest concentrations were measured during grinding of brake linings when local exhaust was not used. Other operations during which the mean concentration exceeded 1 fiber/cm^3 (f/cm^3) were the brushing of brakes, the cleaning of brakes with a wet cloth, compressed air blowing, and grinding of brake linings, even though a vacuum funnel or local exhaust was in use. During all other operations, the mean concentration was under 1 f/cm^3.

The results on passenger cars are presented in Table II. The mean concentration of asbestos exceeded 1 f/cm^3 only during compressed air blowing without exhaust.

The estimated asbestos concentrations during different hypothetical 8-hr workdays are shown in Figure 1. According to these calculations, the average exposure to asbestos during the workday was usually 0.1-0.2 f/cm^3 during brake repair of trucks or buses, and under 0.05 f/cm^3 during repair of passenger car brakes. The heaviest exposure, about 7 f/cm^3, was due to grinding of brake linings for 1 hr without exhaust.

Three examples of the variation of the dust concentration by time as measured by Leitz tyndallometer are shown in Figure 2. The concentration remained at a low level during washing of the brakes, but during brushing and compressed air blowing, the concentration of dust — and probably also that of asbestos — was characterized by high peaks. The concentration, however, decreased to the background level rapidly, usually in 1-2 min.

Also the interday variation in the concentration is worth noting because the frequency of brake maintenance jobs varies with workplace. According to the data of the Finnish Register of Employees Occupationally Exposed to Carcinogens, a car mechanic maintains on average the brakes of 12 trucks or buses in a year (range 1-45, sample of 53 workplaces). The corresponding figure for workplaces maintaining mainly passenger car brakes is 41 (range 3-150, 23 workplaces). Therefore, it is likely that the annual mean exposure is even less than that shown in Figure 1. In addition, the difference in exposure between the heavy vehicles and passenger cars is diminished to some extent. When the daily exposure during brake repair of heavy vehicles is on average 10-15 times higher than during brake repair of passenger cars, the annual mean exposure is only 3-5 times higher.

Discussion

The occupational exposure limit for asbestos is 0.5-2 f/cm^3 (8-hr TWA) in most countries. The Threshold Limit Values (TLVs®) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) are 2 f/cm^3 for chrysotile, 0.5 f/cm^3 for amosite, 0.2 f/cm^3 for crocidolite, and 2 f/cm^3 for other forms of asbestos fibers.[16] In brake maintenance of trucks and buses, the ACGIH TLV for chrysotile asbestos was exceeded only when new brake linings were ground without local exhaust (Figure 1). With all other procedures, the estimated mean concentration was less than 10% of the TLV. The unestimated background concentration of asbestos in the brake maintenance workplaces, however, gives rise to the possibility of underestimation of the TWA concentrations. The background concentration of asbestos measured in this study was, at its highest, the same as the detection limit of the method (0.1 f/cm^3). Similar or slightly higher short-term background concentrations have been found also in other studies.[4,5,17,18] It is not possible to infer exactly the magnitude of the 8-hr TWA background

TABLE I
Asbestos Fiber Concentrations by Operation in Brake Maintenance of Trucks and Buses

Operation	Asbestos Fiber Concentration (f/cm³)			Samples	Workplaces	Range of Sampling Time (min)
	Range	Median	Mean			
Opening of brakes	<0.1-1.9	0.1	0.4	25	13	2-25
Opening and brushing of brakes	<0.1-1.0	0.3	0.3	6	4	1-12
Cleaning of brakes by brushing	0.1-4.5	0.9	1.3	8	3	2-12
Cleaning of brakes with compressed air jet, enclosure and exhaust in use	0.2-3.0	0.7	1.2	9	5	1-14
Cleaning of brakes with damp cloth	1.1-3.3	1.3	1.9	3	2	2-5
Opening of brakes and cleaning of brakes by washing	<0.1-0.3	0.2	0.2	6	4	2-10
Cleaning of brakes by washing with water	<0.1-0.2	0.2	0.1	6	5	4-18
Loosening rivets from brake linings	<0.1-1.6	0.2	0.3	12	9	5-29
Cleaning of brake shoes	0.3-0.4	-	-	2	1	3-5
Punching rivets into brake linin s	0.1-3.5	0.4	0.7	28	9	3-60
Grinding of brake linings with machine, no exhaust	0.3-125	67	56	5	2	4-27
Grinding of brake linings with machine, exhaust in use	0.1-5.9	0.6	1.5	30	4	4-33
Bevelling edges of brake linings with file	0.1-0.9	0.3	0.4	7	3	2-5
Cleaning of brake drums by brushing	0.5-0.7	-	-	2	1	5-6
Grinding of brake drums	0.1-0.3	0.2	0.2	6	4	3-26
Assembling of brakes	<0.1-0.4	0.1	0.2	9	6	6-41
Sweeping floor of garage	<0.1-1.7	0.3	0.6	4	3	2-4
Other, rare operations	<0.1-0.6	<0.1	0.2	5	2	2-30
Background to brake maintenance	<0.1-0.1	0.1	<0.1	3	3	3-68

concentration based on these data, but it is likely to be less than 0.1 f/cm³ in the present Finnish garages. Even though this concentration is low when compared with the occupational exposure limits, it is considerably more than in the urban atmosphere. According to electron microscopic studies, 1 ng of asbestos corresponds approximately to 400 fibers of asbestos as counted by a phase contrast microscope.[19] If this conversion factor is applied to the concentrations measured by electron microscopic methods, the mean concentration of asbestos fibers in urban air has been reported to be below 0.001-0.003 f/cm³ in Great Britain[20] and about 0.002 f/cm³ in 46 cities in the U.S.[21] The concentrations measured near busy road junctions in New York City were 0.004-0.02 f/cm³.[22]

Reports on asbestos exposure during brake maintenance have been published earlier by Rohl *et al.*,[4] Lorimer *et al.*,[5] Hickish & Knight[6,17] and Rödelsperger *et al.*[23] The exposure estimates of this study (8-hr TWA: below 0.01-0.5 f/cm³; annual mean: below 0.01-0.03 f/cm³) are compatible with the results of the recent German study.[23] Hickish and Knight,[6] however, reported the 8-hr TWA of 1.8 f/cm³ for a truck brake service worker and of 0.7 f/cm³ for a worker who maintained the brakes of eleven passenger cars during the workday. These values are higher than those reported in this study. The difference may be due to the different work procedures used during the measurements. The data of Hickish and Knight[6] were published in 1970 and the procedure used was the compressed air blowing without exhaust, whereas the authors' data are mainly from the 1980s when a vacuum funnel is nearly always used during blowing of truck brakes in Finland. Furthermore, in the servicing of passenger cars, the air jet blowing without exhaust is nowadays

TABLE II
Asbestos Fiber Concentrations by Operation in Brake Maintenance of Passenger Cars

Operation	Asbestos Fiber Concentration (f/cm³)			Samples	Workplaces	Range of Sampling Time (min)
	Range	Median	Mean			
Opening and brushing of drum brakes	0.3-0.6	0.4	0.4	4	2	2-13
Cleaning of drum brakes with compressed air jet, no exhaust	<0.1-8.2	0.4	1.5	9	3	1-10
Cleaning of drum brakes with compressed air jet, exhaust in use	<0.1-0.2	0.1	0.1	5	2	2-15
Cleaning of brake drum by brushing	0.1	-	-	1	1	1
Grinding of brake drums	0.5	-	-	1	1	3
Cleaning of disc brakes and changing of brake pads	<0.1-0.2	<0.1	<0.1	8	1	7-38
Changing of brake discs	<0.1	-	-	2	1	23-23
Grinding of brake discs	<0.1-0.2	-	-	2	1	10-10
Changing of clutch linings	<0.1-0.1	<0.1	<0.1	3	2	8-12
Background to brake maintenance	0.1	-	-	1	1	44

used only during cleaning of disc brakes that are not as dusty as drum brakes. The TWA estimates in the present study, and those in the study by Hickish and Knight[6], are thus actually based on different work procedures.

Measurable concentrations of asbestos fibers have been reported to exist up to a distance of 25-30 m from a repairman blowing dust from the brakes with compressed air. According to these results, it takes 15-20 min until the background level of about 0.1 f/cm³ is reached again.[4,5] The present study indicates a more rapid decrease in concentration, but the lower initial concentration and indirect measuring method (tyndallometry) probably explain the difference.

During the grinding of new linings the asbestos concentration has been reported to be 24-72 f/cm³ near the workplace and 0.3 f/cm³ at a distance of 10 m.[4] These concentrations are compatible with the results of the present study. The results demonstrate that the grinding of new linings is an operation that may cause heavy exposure unless the enclosure and the local ventilation are efficient.

The vacuum brush method has been preferred to compressed air blowing with a vacuum funnel, in the servicing of truck brakes.[17] The authors' results indicate that the most preferable method of cleaning brakes is by washing with water. The concentration of asbestos during washing was considerably lower than during brushing, vacuum funnel blowing or wiping with a damp cloth. The concentration during vacuum brush cleaning was not measured because it was not used in any of the 24 workplaces under study.

The likelihood of contracting asbestos-related disease because of brake repair cannot be inferred accurately from the exposure data of this study. Six verified cases of asbestosis among car repair workers, however, have been reported to the Finnish Register of Occupational Diseases during 1964-1984. Four of them were car mechanics, one was a turner, and one a garage supervisor. In addition, two car mechanics in the garage of an asbestos quarry have been affected with asbestosis, but their exposure mainly may have originated from contaminated mine vehicles. It is noteworthy, however, that the past exposures during brake maintenance probably have been heavier that the concentrations reported in this study. Thus the present exposure may indicate a lowered risk of asbestosis in the future.

It is well-established that exposure to asbestos may cause cancer — especially mesothelioma and lung cancer.[24] There are only few epidemiological data on the cancer morbidity or mortality among car mechanics. Nicholson[25] has referred to the data of McDonald and McDonald, according to which at least eleven cases of mesothelioma were diagnosed among automobile maintenance workers in Canada during 1960-1972 and in the U.S. in 1972. In the Federal Republic of Germany, four cases of mesothelioma have been observed among car mechanics.[23] One case of mesothelioma in a brake repair worker has been reported in detail.[26] Based on exposure and x-ray data, Nicholson has estimated that the probability of contracting asbestos-related cancer among automobile maintenance workers is over tenfold less than among insulators and manufacturing workers exposed to asbestos.[25] Additional epidemiological studies are nevertheless required to obtain more accurate information on the cancer risks among car mechanics, and to evaluate the possible contribution of smoking and other chemical exposures to the risks in car repair work.

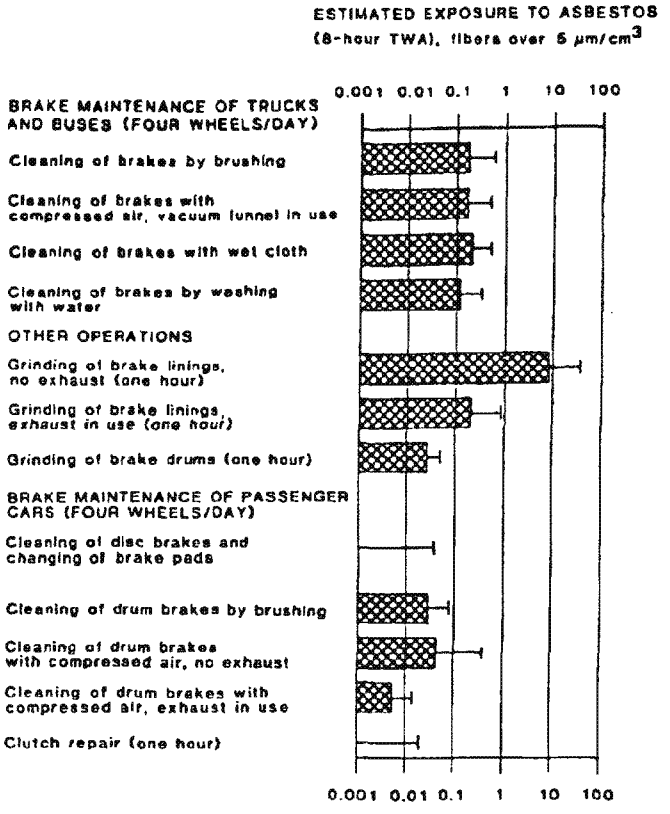

Figure 1 — Estimated mean (bar) and maximal (T-length) exposures to asbestos during a hypothetical workday with different cleaning procedures of brakes; four wheels of a truck, bus or a passenger car are maintained. The background concentration of asbestos is not included in the calculations.

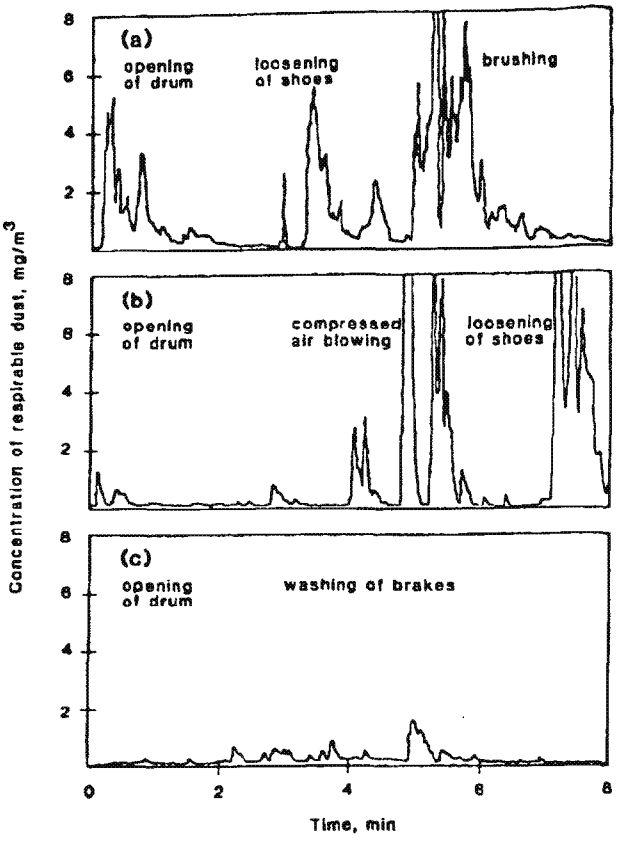

Figure 2 — Variations in respirable dust concentration as measured by Leitz tyndallometer during different cleaning procedures of bus brakes; a) cleaning of brakes by brushing; b) cleaning of brakes with compressed air jet, vacuum funnel in use; and c) cleaning of brakes by washing with water.

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