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Characterization of Asbestos Emissions from Brakes

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ABSTRACT

Particulate emissions from disc and drum brakes were collected and analyzed for asbestos content. Although the original brake lining is about 50% asbestos, the emitted particles average only 0.029% asbestos. The remaining fibers are broken down from thermal and abrasive wear during the braking process. The median length of the asbestos fibers emitted is 0.5 micrometers compared to the original brake fibers which are in the millimeter size range. Increased asbestos emissions occur at higher wheel velocities and deceleration rates. Average automobile emission rates are 2.2 micrograms of airborne asbestos per brake application. The amount of asbestos emitted from brakes is extremely small compared to other asbestos sources. Samples downwind of freeways do not show significant increases over upwind asbestos levels. Reported asbestos levels for tollbooth areas are shown to be consistent with the asbestos emission measurements made in this study.

stress caused during braking. On the other hand, asbestos has been found near roadways and in ambient samples taken near tollbooths.[7,8]

A brake-testing facility was constructed to help resolve the conflicting reports of airborne asbestos emissions from brakes. Brake emissions were collected in simulations of the normal range of driving conditions and particulate samples were analyzed for asbestos content. The significance of brake emissions will be considered on the basis of the contribution of brakes to ambient asbestos levels.

EXPERIMENTAL

A brake-wear test facility was designed for generation and collection of brake emissions. Design of the facility and operational details of particulate collection have been described previously.[9,10] Nuclepore or Millipore filters were used for asbestos collection and analysis. These were analyzed by optical and electron microscopy.

Optical measurements were made using the standard OSHA procedure for counting fibers greater than 5 micrometers in length. Using a phase-contrast technique at a magnification of 400X, 1/10 000th of the total filter area is scanned.

Because asbestos fibers occur in a very wide size range, it seems appropriate to consider mass concentration in addition to fiber counts. In order to make such calculations for the optical measurements we assumed that regardless of length each fiber had a diameter of 0.25 micrometer and a density of 2.56 g/cm^3.

Electron microscopy was necessary for counting and sizing the smaller fibers. Transmission electron microscopy was found to be preferable to scanning electron microscopy. A transmission electron micrograph of a brake

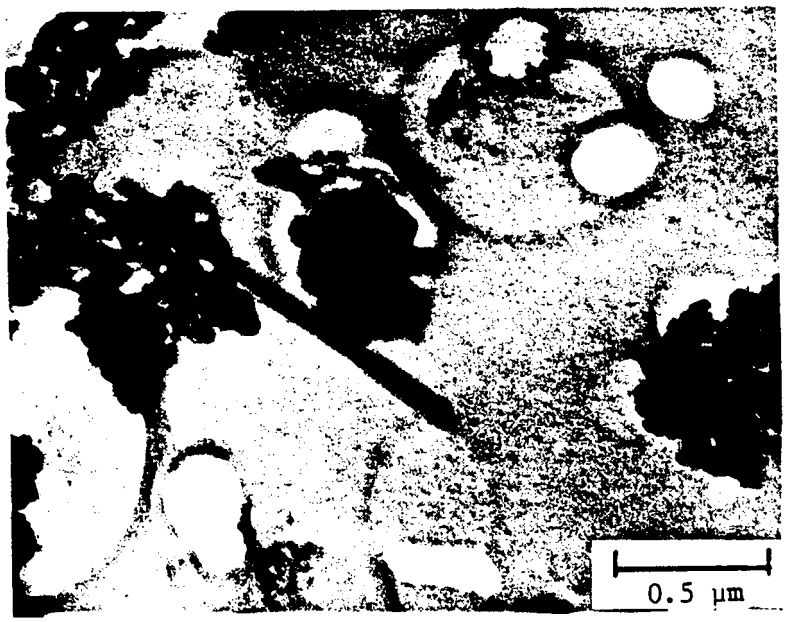

Figure 1. Transmission Electron Micrograph of Brake Debris Showing Asbestos Fiber (40 000 X).

Table I. Asbestos Emissions from Brakes

Test	Velocity	Deceleration	Mass Particulate	Mass Asbestos		% Asbestos
				TEM	Optical	
	km/h	m/s^2	µg	ng	ng	
Disc Brakes						
26B	40	1.8	88	3.5	-[a]	0.0040
28	40	4.9	443	62	ND[b]	0.014[c]
29B	40	4.9	109	3.7	-	0.0033
14B	64	1.2	609	9.7	-	0.016
17B	64	1.8	622	57	-	0.0093
32	64	1.8	73	3.1	-	0.0042
34B	64	1.8	430	4.1	-	0.00095
37	64	1.8	98	180	-	0.18
6	64	2.5	82	13	75	0.11
7	64	2.5	2985	85	ND	0.0028[c]
8A	64	2.5	60	14	-	0.024
8B	64	2.5	734	130	-	0.017
9	64	4.9	99	11	44	0.056
10	64	4.9	2817	76	ND	0.0026[c]
11A	64	4.9	85	29	13	0.049
11B	64	4.9	399	8.4	-	0.0021
2	65	0.2	111	8.5	19	0.025
3	65	0.2	381	12	-	0.0032
4	65	0.3	141	11	62	0.052
5	65	0.6	364	26	44	0.019
22	88	1.8	452	38	-	0.0085
36	88	1.8	341	14	-	0.0041
41	88	1.8	498	13	-	0.0027

(continued on next page)

The average number and mass of small and large fibers per filter are shown in Table II. The small fibers greatly outnumber the large fibers by about 300 to 1. However, the mass is evenly divided between the small and large fibers. There are about 90 000 total fibers/ng of asbestos. This is similar to Thompson's findings of 10^5 fibers/ng.[12]

Table II. Comparison of Small and Large Asbestos Fibers[a]

	Disc	Drum
Small fibers/filter	3.4×10^6	3.4×10^6
Mass small fibers (ng)	12	19
Small fibers/ng	2.9×10^5	1.8×10^5
Large fibers/filter	0.7×10^4	1.5×10^4
Mass large fibers (ng)	17	37
Large fibers/ng	430	405
Small/large fibers	460	230
Small/large Mass	0.68	0.51
Total fibers/ng	119 000	61 000

[a] Small fibers are less than 5 micrometers in length
Large fibers are more than 5 micrometers in length

The average asbestos content in the emitted airborne particulate from drum brakes ranged from 0.0020 to 0.19% mass, with an average of 0.031%. The disc brake values ranged from 0.00095 to 0.18%, with an average of 0.027%. These values are similar to those found by Anderson et al.[13] (0.002%) and by Jacko and DuCharme (0.23%),[6] but are much lower than values of 2 to 15% reported by Rohl et al.[1] However, Rohl et al. based their results on x-ray diffraction which is not selective enough to distinguish between chrysotile asbestos and similar minerals. The x-ray

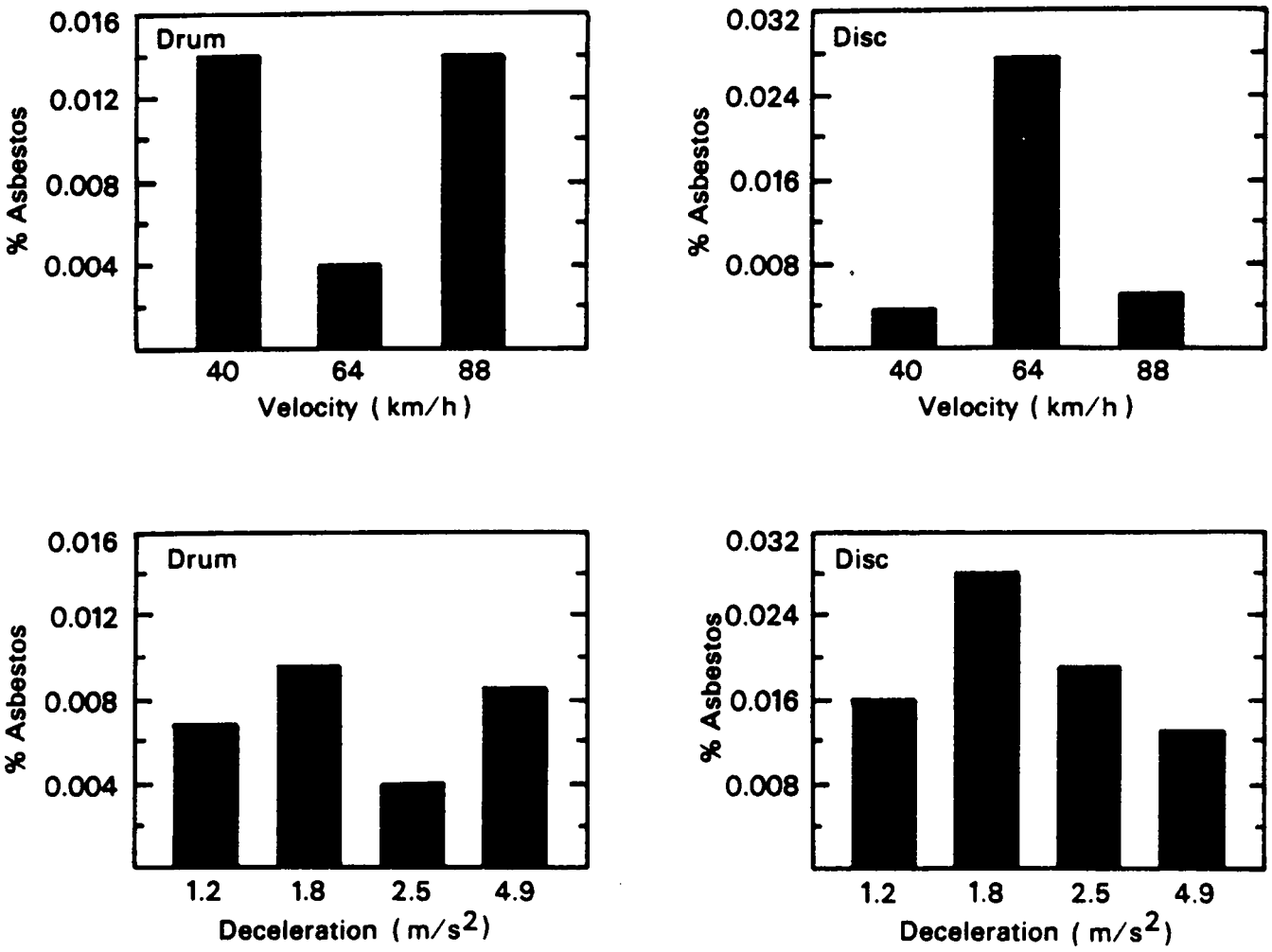

Figure 2. Asbestos Content of Airborne Brake Emissions as a Function of Velocity and Deceleration.

and 0.040% in roadway material and four brakes per vehicle, there is an average of 2.2 micrograms airborne asbestos, 0.63 microgram roadway asbestos, and 1.8 micrograms entrained asbestos per brake application or a total of 4.6 micrograms asbestos per vehicle per stop. The wheel-entrained estimate may be high since the wheel was cleaned after each test. There were 114-million registered automobiles in the United States in 1977, traveling an average of 16 000 km each.[14] The number of vehicle stops per unit distance has been determined for a variety of driving cycles and averages 1.2 stops/km (2.0 stops/mile).[6] Therefore, there would be 4.9 metric tons of airborne asbestos, 1.4 metric tons of roadway asbestos, and 4.0 metric tons of entrained asbestos for a total of 10 metric tons of asbestos emitted annually from brakes. This is somewhat lower than Jacko and DuCharme's estimate of a maximum annual emission of 27 metric tons from automobiles.[6] These values can be compared to total man-made disposals and emissions of asbestos in 1974 of 534 554 metric tons of which 532 307 was disposed to land, 2093 was emitted to the air, and 154 was emitted to the water.[2] Asbestos emitted from automobile brakes accounts for approximately 0.0019% of the total U.S. asbestos emissions, or 0.23% of airborne asbestos emissions. Brake asbestos emissions appear to be an extremely small contributor to total asbestos emissions.

DISCUSSION

Despite the very low asbestos emissions from braking, there are literature reports of higher than background asbestos levels in the air near roadways and tollbooths and in roadway debris. These reports will be evaluated in terms of our experimental results.

Urban Asbestos Levels

Asbestos fibers have been measured in areas far removed from asbestos sources. Rural values have been reported of 0.01 to 0.1 ng/m^3.[12] Urban

Asbestos Levels Near Freeways and Tollbooths

Asbestos levels have been studied downwind of freeways, where brake emissions are expected to be high. Alste et al.[17] measured airborne asbestos concentrations at three urban sites near freeways in Australia. A measurable asbestos level of 5×10^5 fibers/m^3 was found at only one site with most fibers less than 2 micrometers in length. Braking was suggested as the source of this asbestos although there was no attempt to measure upwind concentrations. The mass can be determined by estimating the volume of fibers, assuming a maximum length of 2 micrometers, a diameter of 0.05 micrometer, and a density of 2.56 g/cm^3. The fiber count of 5×10^5 would correspond to a mass of about 5 ng/m^3. This value is lower than asbestos concentrations in some other urban areas.[15]

Murchio et al.[18] measured asbestos levels downwind of four Los Angeles freeway sites. They found 0 to 12 fibers/L, with an average mass of 27 ng/m^3, but there was no significant difference in upwind and downwind samples. No correlation was found with asbestos levels and number or speed of vehicles. One sample was also analyzed from a toll plaza, an area where heavy braking occurs. During the 2-hour sampling period, 11 500 cars passed through the plaza. Asbestos levels were found to be only 1.4 fibers/L, a value indistinguishable from background. The median length of asbestos fibers around the Los Angeles freeway was about 8 micrometers, compared to 0.5 micrometers for the fibers we found emitted from brakes. Based on the asbestos levels near freeways and the asbestos fiber length, it appears that automotive brake emissions are not a significant contributor to ambient asbestos in Los Angeles.

Asbestos levels have been measured at several sites in Connecticut[16] in conjunction with a proposed state air quality standard of 30 ng/m^3. The proposed standard is quite stringent, approximately 0.1% of the level set by OSHA for persons working with asbestos. Rural levels ranged from less than 1 to 6 ng/m^3 and urban levels ranged from less than 1 to 9 ng/m^3.

Table III. Asbestos in Roadside Dust

Sample	Location	Mass Dust (mg)	Asbestos Mass <5 μm (ng)	Asbestos Fibers/g >5 μm	Asbestos Mass (a) >5 μm (ng)	% Asbestos
1	MD	2.18	44	9×10^6	87	0.006
2	MD	0.81	7.3	6×10^7	210	0.027
3	MD	2.06	5.2	-	-	0.0002
4	CA	2.06	2.4	1×10^6	43	0.002
5	CA	2.01	1.7	-	-	0.0001
6	CA	2.08	0.52	1×10^7	87	0.004

(a) The mass was calculated based on the 230 large fibers/ng found from brake-wear mass data.

CONCLUSIONS

Asbestos emitted during braking was examined using a specially designed brake-testing chamber. The procedure used to identify the asbestos content is quite similar to the method being considered by the EPA. The average asbestos content in particles emitted from brakes was 0.031% from drum and 0.027% from disc brakes. Over 99.9% of the original asbestos has been degraded during the braking process to nonfibrous forms. The median length of the airborne asbestos is 0.5 micrometer. The percentage asbestos in the brake emissions does not appear to be a function of velocity or deceleration rate. However, increased asbestos emissions occur at higher velocities and decelerations as more particles are emitted. The total annual asbestos emission from automobile brakes in the United States is expected to be 10 metric tons, which is very small compared to other asbestos sources.

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