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Determining the Frequency of Asbestos Use in Automotive Brakes from a Fleet of On-Road California Vehicles

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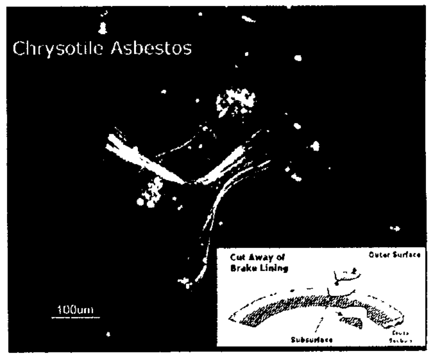
ABSTRACT: Asbestos is a known human carcinogen, and recent regulation in California limits asbestiform fibers in brakes to trace levels beginning in 2014, although there is no corresponding federal requirement. In order to gauge the current prevalence of asbestos use in automotive brake applications, the California Air Resources Board tested brake linings from 137 light- and medium-duty vehicles and 54 heavy-duty vehicles. Only about 3% of the light- and medium-duty vehicle brake linings contained chrysotile asbestos. All of those brake linings were drum-type shoes, which are generally being phased out. No asbestos was found in low mileage vehicles presumed to have their original stock linings from the vehicle manufacturer. Additionally, no asbestos was found in the heavy-duty vehicle brake shoe linings sampled. Given the small percentage of vehicle brake linings with asbestos observed, it appears that the prior federal ban that was subsequently overturned, in combination with a threat of litigation, has reduced asbestos use in brake linings. However, our study was limited in scope and without a national ban, the current and future prevalence of asbestos in brakes is uncertain, suggesting the need for continued monitoring of materials released as toxic air contaminants in normal braking operations.



■ INTRODUCTION

Asbestos has been used in many products, including automotive brake linings, cements, millboard, roofing materials, floorings, heat-resistant gaskets, and electrical wiring insulation.[1] For decades, asbestos was the primary material in automotive brake linings due to its thermal stability, low wear rate, low cost, and other useful characteristics.[2] It is estimated that in 2003, 10% of the estimated world sales of chrysotile asbestos was used for brake linings and clutch facings.[3] Chrysotile asbestos was eventually shown to be a human carcinogen and has become the source of much debate and an aggressive litigation industry over the past few decades. Central to the litigation are risks to auto mechanics from handling brake linings containing asbestos, as identified by Castleman et al.[4] and reviewed subsequently by Lemen[5] and Welch.[6] However, asbestos particles are also released into the general environment as a result of routine driving and braking, with airborne concentrations of asbestos close to major highways and roadways up to 3–6 times higher than at locations away from roadways.[7,8]

As of 2011, 55 countries, including all member states of the European Union, have banned the use of all forms of asbestos in manufactured products.[9] In 1989, the United States Environmental Protection Agency (USEPA) issued a rule that would have phased out the manufacture, import, and processing of original equipment manufacturer (OEM) asbestos-containing automotive brakes by 1996,[10] but that rule was subsequently overturned in 1991 by the fifth Circuit Court of Appeals.[11] In reaction to the impending U.S. asbestos ban, rising concern in other industrialized countries about asbestos health effects, and ongoing litigation, manufacturers of brake linings began searching for asbestos alternatives. A 1998 report indicated 25% of new vehicles built in the U.S. with OEM drum brakes contained asbestos,[12] but by 2004 a USEPA survey of the nine major OEMs found that none of the major manufacturers sold asbestos brakes in new vehicles or as replacement parts in the U.S.[13] Instead, OEMs were opting to use alternative formulations such as metallic, semimetallic, synthetic, and ceramic fibers. However, no legal impediment to using asbestos exists, and a 2007 Occupational Safety and Health Administration (OSHA) survey found that some vehicles of two OEMs were still equipped with asbestos-containing friction products.[14] Furthermore, aftermarket brake linings containing asbestos are still available as demonstrated by Senator Patty Murray (D-WA), who brought an asbestos brake lining purchased by her staffer to a 2007 U.S. Senate Subcommittee hearing in an effort to dispel the myth that asbestos products are no longer available in the U.S.[15] Current litigation regarding asbestos-related cancer may lead to further reductions in asbestos use, and even greater nationwide reductions may occur due to a California ban on asbestos in friction materials that goes into effect in 2014.[16]

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Asbestos is known to cause lung cancer, pleural fibrosis (scarring of the lung tissue), and mesothelioma, a cancer of the membrane that lines the body cavities and some internal organs.[17] The onset of mesothelioma can involve a latency of 10−50 years from the time of exposure, thereby accounting for current litigation based on exposures from past decades. The etiology of mesothelioma and other asbestos-related diseases involves various environmental sources of asbestos, most of which are anthropogenic. Historically, asbestos fibers of toxicological concern have been those that can penetrate deep into the lungs, which are typically between 5 and 10 μm in length. As such, OSHA has permissible exposure limits on airborne asbestos fibers, which are defined as those 5 μm or longer, with an aspect ratio (i.e., length-to-width ratio) of 3:1 or longer.[18] However, the definition of health-relevant fibers is somewhat variable and a recent review by Lemen[5] found that there was significant evidence for toxicity of asbestos fibers less than 5 μm in length, which outnumber fibers greater than 5 μm in brake wear debris by a ratio of 300:1.

Relevant motor vehicle sources of asbestos are brake linings, clutch facings, gaskets, and automatic transmission components. Of importance in this context is the inhalation exposure to brake wear dust emitted from the vehicle and entrained in ambient air. Due to the high heat generated during braking, much of the surface asbestos is converted to forsterite, a nonfibrous material. Thus, both forsterite and short-fiber length chrysotile asbestos are present in brake wear debris. While the toxicity of chrysotile asbestos is well documented, the health risk associated with forsterite exposure is not well studied, although evidence suggests that both forsterite and brake lining dust have a cytotoxic effect.[5] The percentage of brake wear mass that becomes airborne has been reported as anywhere between 7 and 70%.[2,19−23] Mechanics performing brake replacements are especially susceptible to high exposures.[4]

In 2010, brake wear accounted for 19% of California's on-road motor vehicle emissions inventory of PM_{10} (particulate matter ≤ 10 μm), as based on the California Air Resources Board's (CARB's) model for estimating California's motor vehicle emissions.[24] For $PM_{2.5}$ (particulate matter ≤ 2.5 μm), brake wear accounted for 11% of the 2010 on-road motor vehicle emissions inventory.[24] Human exposure to brake-related asbestos emissions is likely to be the highest in urban and suburban environments compared to rural environments.[7,8] Currently, the proportion of ambient asbestos and the associated level of human exposure due to brake wear emissions in California are unknown. Given that human exposure may be occurring, and the fact that asbestos is a known human carcinogen, an assessment was made to gauge the prevalence of asbestos use in automotive brake applications. The purpose of this study was to estimate the current level of asbestos use in the California on-road fleet of light-duty, medium-duty, and heavy-duty motor vehicles, and evaluate the regulatory implications of the findings.

MATERIALS AND METHODS

Light-Duty and Medium-Duty Vehicles. Vehicles were procured under CARB's 18th Vehicle Surveillance Program (VSP18 program), a test program routinely conducted for the purpose of assessing emission levels of light-duty and medium-duty vehicles representative of the on-road California fleet. Under this program vehicles are randomly selected from a registered-vehicles database maintained by the California Department of Motor Vehicles. Selection of approximately 300 vehicles was based on stratified sampling by model year (i.e., weighted by the number of vehicles still on the road). The model year of the vehicles sampled ranged from 1989 to 2006 and sampling was terminated in July of 2008. The sampling area encompassed an approximate 50 mile radius from the CARB, El Monte office, located roughly ten miles east of downtown Los Angeles. This area includes all of Los Angeles County, Orange County, and portions of neighboring counties, which are likely to be representative of urban/suburban populations in southern California. Vehicle selection is also presumed to include approximate representation across all income levels, all manufacturers, all models, and targeted vehicle classes. However, consideration of potential biases in this study is given in a later section.

Sampling of these vehicles was halted after 137 vehicles, when this subsample of vehicles was not statistically different (at $p \leq 0.05$) from the target fleet of 300 with respect to model year ($p = 0.069$, $t = 2.04$, df = 32) and manufacturer ($p = 0.403$, $t = 2.03$, df = 7) based on a paired sample, two-tailed t-test (using the arcsine-square root transformation). Although not statistically significantly different, the mean model year age for the target fleet was slightly lower than our sample fleet (1996 versus 1999), with our sample fleet distribution skewed slightly more toward newer model vehicles.

Replacement of brake linings for the light- and medium-duty vehicles was performed by certified CARB auto mechanics. Brake lining samples were bagged and labeled with bar-coded vehicle identifiers. The following samples of brake lining were collected: (a) the two inner disk linings from the front axle and (b) the two inner disk linings from the rear axle, or in the case of drum brakes, the two primary drum linings from the rear axle. One front and one rear lining from each vehicle was sent the California Department of Public Health Environmental Health Laboratory (EHL) for asbestos analysis, and the other set was retained as "back-up."

As part of the vehicle procurement protocol conducted under the VSP18 program, the owner was given a questionnaire to assess use, condition, and integrity of the vehicle. Questions on household income and where vehicle repairs were typically conducted were also asked. Vehicle owners who agreed to participate in the program were asked if they wanted their brakes replaced at no cost. Regarding the replacement of brake linings in particular, the vehicle owner was also asked if the front and/or rear brake linings on their vehicle were ever replaced and, if so, how long ago. The answer to this question was intended to assist in the determination of whether the linings on the vehicle were the original linings installed on the vehicle at the time of purchase, or if they were aftermarket linings. This distinction was considered important because communications with automotive trade groups and manufacturers strongly suggested that both U.S. and foreign auto manufacturers were no longer selling new vehicles equipped with brake linings containing asbestos. A typical vehicle is likely to have its brake linings replaced anywhere from 4 to 8 times during its lifetime, and in many cases with the use of aftermarket brake linings (i.e., non OEM).

Heavy-Duty Vehicles. The sampling of heavy-duty vehicles was initiated in November 2008 and terminated in October 2009. The combined fleet of 54 heavy-duty vehicles consisted of line-haul tractors, line-haul trailers, city-delivery vehicles, motor homes, dump trucks, and buses. Due to the large size and mass of heavy-duty vehicle brake linings, two- to four-inch square pieces were removed for analysis. The sampled pieces

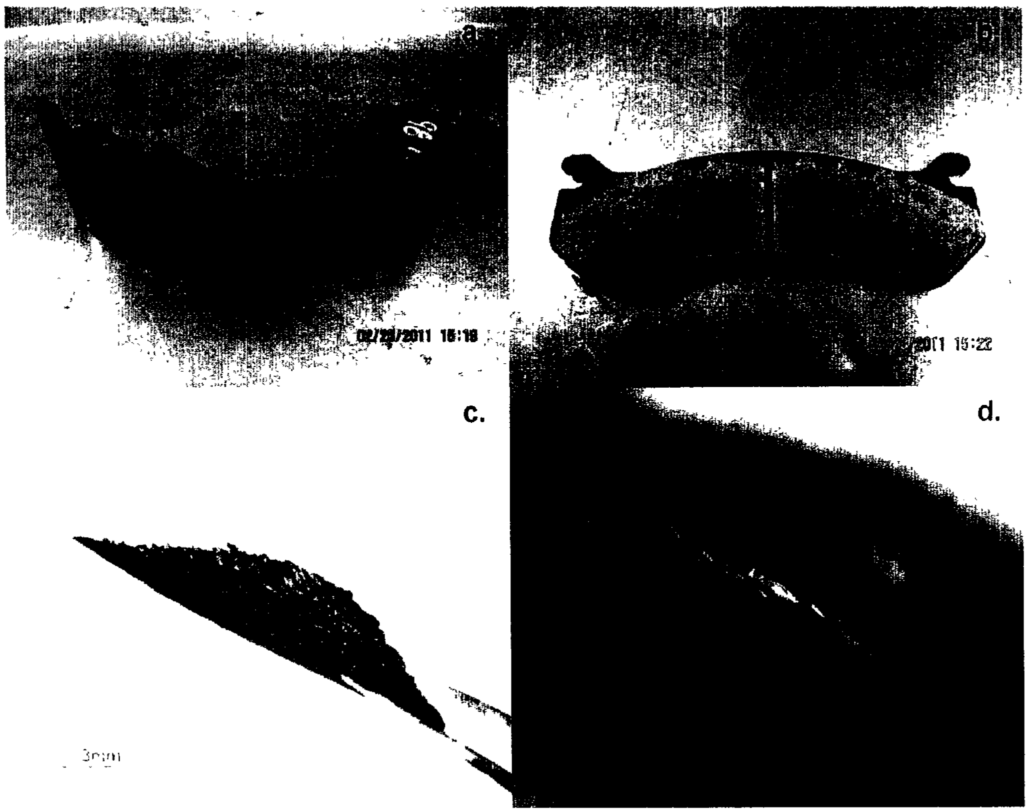

Figure 1. Images for subsample from brake linings showing (a) sampled drum brake lining, (b) sampled disk brake lining, (c) 6.3× stereozoom microscope image of subsample from drum brake lining, and (d) 32× stereozoom microscope image of drum brake subsample showing fibrous asbestos <50 μm from the outer surface.

were bagged for transport and labeled with appropriate identifiers. Thirty-six heavy-duty vehicles were obtained from one repair shop in the Los Angeles area alongside a major California highway. In all but two vehicles, both the steer and drive axle brake linings were sampled. Twelve samples were obtained from a trailer repair facility located in the Los Angeles suburb of Compton. Samples collected from this facility consisted of stockpiled linings with no associated vehicle information other than the fact they were removed from line-haul trailers. Linings from this stockpile were arbitrarily selected, with the only criterion being a composition visually different from all others, for example, based on presence or absence of copper particles or visually different fibers. Five samples were obtained from a repair shop at French Camp, a community located near the city of Stockton, and one additional sample was from a bus owned by a school district in Anaheim, a city in Orange County.

Asbestos Analysis. Asbestos analysis was conducted by EHL, which has state-of-the-art facilities for identification of the following species of asbestos: chrysotile, actinolite, tremolite, crocidolite, anthophyllite, and amosite. A screening procedure was developed based on established National Institute for Occupational Safety and Health (NIOSH) methodology, which allowed for the qualitative identification (presence or absence) of chrysotile asbestos, the most common asbestos mineral used in automotive brake linings. All brake linings were qualitatively screened for asbestos using techniques specified in NIOSH Method 9002,[25] which uses low-power stereozoom microscopy and polarized light microscopy (PLM) and has a detection limit of <1% asbestos content. For light- and medium-duty vehicles, samples of each brake lining were prepared by breaking off pieces of the brake lining in a ventilation hood with the use of a hammer and awl (Figure 1a and b). For heavy-duty vehicles, this was not necessary since these samples were already removed from the backing of the brake lining. All brake lining samples were then inspected under the stereozoom microscope Using a scalpel and forceps, brake material was removed from the brake lining. For the light- and medium-duty vehicle brake linings containing asbestos, brake material was removed from three locations in the following manner: (a) by scraping from top to bottom along the cross-sectional edge, referred to as "cross section," (b) by scraping the outer frictional surface, referred to as "outer surface," and (c) by scraping the inside surface of a piece broken off from the bottom of the brake lining, referred to as the "subsurface sample." Analysis of these brake lining subsamples was performed in order to account for any heterogeneity in the spatial distribution of asbestos, the presence of wear dust, and/or the thermochemical transformation of asbestos. Brake lining samples were placed in 1.550 refractive index Cargille oil on a slide with a coverslip. PLM was used to characterize the fibers in the brake material with respect to the following key optical properties: fiber morphology, color under plane polarized light, extinction angle under crossed polars, sign of elongation using a full wave plate, and birefringence as measured by dispersion staining (Figure 2). If any fibers were "positive" for chrysotile, the sample was ashed in a muffle furnace at 500 °C for 24 h to remove the interfering organic matrix, thereby facilitating improved asbestos identification and quantitation without denaturing the asbestos. The asbestos content was determined by

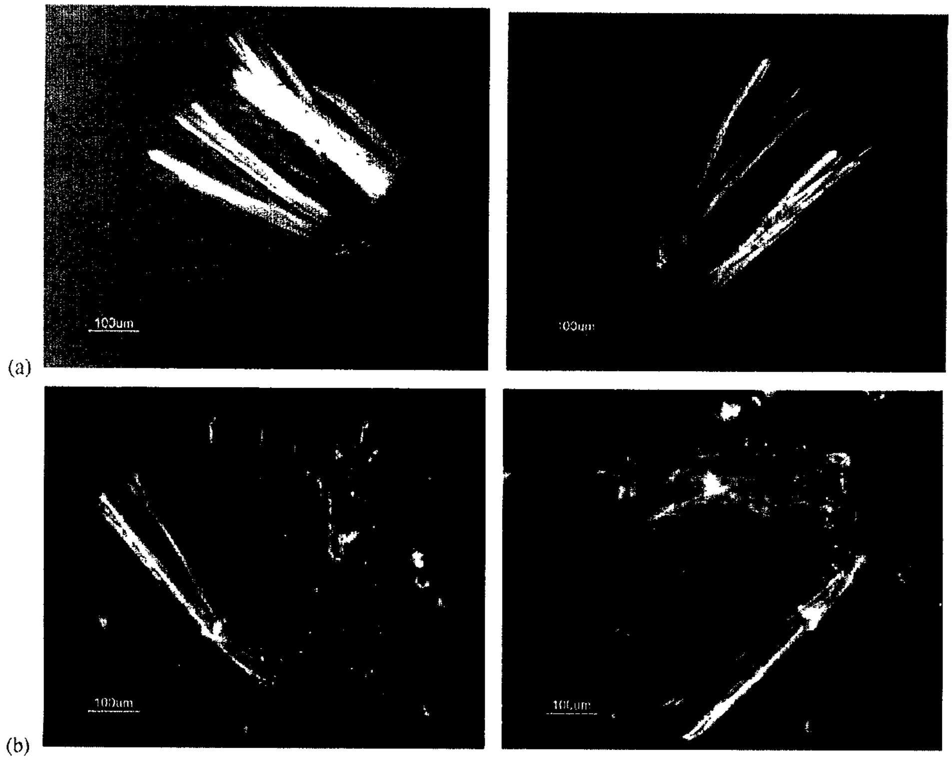

Figure 2. 100X PLM analysis of chrysotile asbestos subsampled from a 1997 Oldsmobile Silhouette drum brake lining. (a) Positive sign of elongation under crossed polarizers with full wave plate. (b) Characteristic dispersion staining colors.

Table 1. Summary Data for Light-Duty, Medium-Duty, and Heavy-Duty Vehicles Sampled

vehicle type	no. vehicles	average model year	average odometer (miles)	average GVWR (lbs)[a]	no. axles sampled	no. samples analyzed	no. vehicles with asbestos[b]
light-duty + medium-duty	137	1999	100 390	4856	274	274	4
heavy-duty line haul	13	2004	386 070	49 881	27	33	0
heavy-duty city delivery	10	1999	165 571	22 629	21	36	0
heavy-duty motor home	7	2001	58 235	16 936	14	24	0
heavy-duty bus	3	1998	313 852	38 667	4	8	0
heavy-duty trailer[c]	12[c]	—[c]	—[c]	—[c]	12[c]	12[c]	0
heavy-duty other	9	1999	132 205	38 289	23	35	0
heavy-duty total	54	2001	219 373	32 554	101	148	0

[a]GVWR = gross vehicle weight rating, defined as the maximum allowable total weight of a road vehicle or trailer carrying a full load, inclusive of vehicle weight, fuel, passengers, cargo, and trailer weight. [b]All brake linings with asbestos were rear drum brakes. [c]Trailer brake linings taken from a stockpile at a trailer repair facility and with each lacking associated vehicle information. These assumed to originate from different axles based on differences in visual appearance, i.e., visual composition.

measuring the weight percent asbestos in the ash, correcting for the amount of matrix removed, and then calculating the implied percentage in the original brake.

RESULTS AND DISCUSSION

Fleet Characteristics. Characteristics of the vehicle fleet sampled are given in Table 1. In total, 422 brake lining samples from light-, medium-, and heavy-duty vehicles were analyzed for asbestos. Of the 137 light- and medium-duty vehicles sampled, the average model year was 1999 with an average odometer of 100 390 miles, and an average weight of 4856 lbs gross vehicle rate weighting (GVWR), which is defined as the actual vehicle weight plus its maximum allowable load. Of this sample fleet, only four vehicles had brake linings that contained asbestos, which in all cases was identified as chrysotile asbestos.

The heavy-duty fleet consisted of six vehicle categories representing various specialties of use. Of the 42 vehicles for which vehicle information was available, the average model year was 2001, the average odometer reading was 219 373 miles, and the average weight 32 554 lbs GVWR. The stockpiled brake linings from the heavy-duty trailers were estimated by the owner to have been removed from vehicles over the 2005–2008 time frame, but no vehicle-related information was available for these samples. No asbestos was found in any of the heavy duty brakes that were sampled.

Asbestos is used primarily in drum brakes, though web-based searches have indicated that asbestos-containing disk brakes are

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Table 2. Asbestos Content and Vehicle Description in Brake Lining Samples with Asbestos[a]

	vehicle information			sample information				
vehicle no.	model year	mfr	model	sample location on lining[c]	wt % asbestos	collection date	analysis date	edge code[d]
7R[b]	1997	Oldsmobile	Silhouette	cross section	26	1/23/07	6/7/07	FASA-RX-FF
				outer surface	23		9/9/08	
				subsurface	32		9/9/08	
				mean =	27			
76	1989	Cadillac	Coupe DeVille	cross section	30	11/5/07	12/24/07	no edge code
				outer surface	20		9/9/08	
				subsurface	26		9/9/08	
				mean =	25			
116	1990	Ford	Thunderbird	cross section	32	3/28/08	4/23/08	FASA-RX-FF
				outer surface	27		9/9/08	
				subsurface	30		9/9/08	
				mean =	30			
140	1998	Toyota	4 Runner	cross section	33	7/11/08	7/28/09	FASA-OBX-FF
				outer surface	25		9/9/08	
				subsurface	29		9/9/08	
				mean =	29			
				Grand Mean =	27.5			

[a]Vehicles procured under Surveillance Program No. 18, Project No. 2S06C1 and Project No. 2R0609. [b]An "R" after the vehicle no. indicates that the vehicle was rejected from the study due to excessive mechanical problems. [c]See text for details regarding the methods and location from which samples were taken. [d]The edge code is an identification marking stamped on the edge of the brake lining.

available on the market. The four vehicles found with asbestos in this study were all equipped with front disk and rear drum brakes, with asbestos present only in the drum brakes. Currently, the majority of light- and medium-duty vehicles have disk brakes on all four wheels. Of the light- and medium-duty vehicles we sampled, 60% employed only disk brakes, with the remainder utilizing front disk brakes and rear drum brakes.

The current study should be viewed as a "snapshot" in time, conducted over a relatively short period of only 18 months for the light- and medium-duty fleet (beginning January 2007) and 12 months for the heavy-duty fleet (beginning June 2008). The heavy-duty trailer brake linings were estimated to have been removed from vehicles over the 2005–2008 time frame, but with no associated vehicle information available. Thus, caution must be exercised in the interpretation of these data relative to past or future prevalence of asbestos in the on-road vehicle population.

Sample Bias. Five possible sources of bias in the light- and medium-duty vehicle populations sampled include: (a) over-representation of low-cost vehicles resulting from the offer of a free brake lining replacement and a free "loaner" vehicle, (b) over-representation of high mileage vehicles also resulting from the offer of a free brake lining replacement and a free "loaner" vehicle, (c) under-representation of four-wheel drive vehicles resulting from limitations in dynamometer emissions testing, (d) under-representation of high-cost vehicles from possible owner concern of vehicle damage, and (e) geographic variation, resulting in either an over-representation or under-representation in the supply and thus use of brand-specific aftermarket brake linings. With particular respect to geographical representation, the nearness of a brake repair facility to particular manufacturers and distributors of brake linings could bias the brands of brakes sold into that local market and sold to a particular repair shop. Investigation into the brake lining "edge codes" indicate that three of the four brake linings containing asbestos originated from the same Canadian manufacturer, with Canada being one of the largest producers of asbestos in the world; the manufacturer of the fourth lining is unknown due to an illegible edge code. Since the study described herein was conducted in southern California, there exists the possibility that the incidence of asbestos linings may be higher in northern California and the more northern U.S. states since, to our knowledge, no brake manufacturer in the U.S. produces asbestos-containing brake linings.

Similar to the light- and medium-duty population of vehicles sampled, there was a geographic bias in the heavy-duty vehicles sampled, namely, a bias toward southern California. In addition, the heavy-duty vehicles were serviced on site at their respective facility, thus requiring the selection of facilities that were willing to coordinate with CARB staff. Besides resulting in additional logistical complexities, this also resulted in the inability to collect a random sample. A sampling issue and likely bias specific to the stockpile of heavy-duty trailer brake linings was selection of friction material samples based solely on visual differences, resulting in sampling that was not random.

Asbestos Content. Analysis of the three subsamples from each of the four light-duty and medium-duty vehicles with asbestos brake linings are reported in Table 2, and include mean values of the relative asbestos contents for each vehicle These means ranged from 25 to 30 wt %, with a mean of 27.5 wt % ($n = 4$). A two-way ANOVA (analysis of variance) was conducted to assess the presence of any statistically significant differences ($p \leq 0.05$) between asbestos brake lining content of the four vehicles, as well as any differences between the three locations where the brake subsamples were taken ($n = 12$). No statistically significant differences ($F_{3,6} = 1.76$, $p = 0.252$) were found among the four vehicles with respect to asbestos content in the brake lining samples. However, there was a statistically significant difference ($F_{2,6} = 7.47$, $p = 0.023$) found among the three locations from which subsamples were taken. A posthoc

Table 3. Characteristics of the Four Vehicles with Asbestos Brake Linings[a]

vehicle no.	model year	odometer (miles)	GVWR[c] (lbs)	comments
7R[b]	1997	101 947	5357	damage: stains on door, 4 broken items outside, 13 paint scratches (one deep metal), 2 dents/dings, one chipped paint, approximately 40 items indicated on damage diagram/report, one deep-metal scratch
				mechanical. leaking radiator, approximately $1300 in repairs conducted by dealership, noise when turning sharp left or right
				household income $35–50K
				other: vehicle failed Smog Check on the first test, dirty oil, maintenance typically conducted by garage/service station
76	1989	167 482	4507	damage. carpet stains and tears, rips on passenger door, broken light on driver's side, steering wheel damage, some dents on roof, cracked windshield, approximately 20 items total on damage diagram/report
				mechanical: driver's side window has operational problems, repaired 2 vacuum lines and O2 sensor
				household income: $50–70K
				other· failed two emission tests for nitrogen oxides, vehicle maintenance typically conducted by garage/service station, owner rarely follows recommended maintenance schedule
116	1990	180 541	4885	damage· rear-view mirror fell off, driver's seat leans to left, weak AC, brakes squeak, stains on seat and carpet, approximately 41 items total on damage diagram/report
				mechanical· two drums replaced, rear spring kit, tow wheel cylinder, muffler was repaired, had oil leak with puddle on ground
				household income: >$90K
				other· failed one emission test for nitrogen oxides and hydrocarbons, low coolant level in reservoir, maintenance typically conducted by garage/service station
140	1998	142 465	5250	damage: front windshield pitted, approximately 29 items total on damage diagram/report
				mechanical: master cylinder rear right axle seal replaced
				household income: declined
				other: maintenance typically conducted by dealership or owner

[a]Vehicles procured under CARB's Light-Duty Vehicle Surveillance Program No. 18. [b]"R" after the vehicle no. indicates that the vehicle was rejected from the study due to the need for excessive mechanical repairs. [c]GVWR = gross vehicle weight rating, defined as the maximum allowable total weight of a road vehicle or trailer carrying a full load, inclusive of vehicle weight, fuel, passengers, cargo, and trailer weight.

Tukey HSD (honestly significant difference) test indicated that the cross-section samples contained significantly more asbestos than the outer surface samples, with the subsurface sample asbestos content lying between these extremes. The outer surface was expected to have the least amount of asbestos due to the conversion of the asbestos to forsterite through frictional heating, which creates a relatively thin, asbestos-poor layer (Figure 1c 1d). However, we should note that the p-value of 0.023 indicates only a weak trend due, in large part, to the limited sample size. These results indicate that care should be taken in sampling brake linings for asbestos content by avoiding sample contamination from the brake dust and also by avoiding sampling any subsurface forsterite resulting from frictional heat.

The average approximate asbestos content of 27.5 wt % found in this study can be compared to previous estimates of 20–60 wt %.[22,26–29] However, only a very small fraction of the original asbestos survives the thermal temperatures experienced during a braking event due to the conversion to forsterite.[5] The percentages by weight of airborne asbestos found in brake wear dust worn from asbestos brake linings are typically less than 1.0 wt %, ranging from 0.02 to 0.50 wt %.[21,22,30] Variability in these estimates is likely due to differences in the asbestos contents of the brake linings, as well as differences in the driving cycles or the number and intensity of stopping events, and the sampling methodology used to collect and size the asbestos fibers. Such variability exacerbates any attempt to estimate the contribution of motor vehicle brake wear emissions to the ambient air concentration of asbestos.

Characteristics of Vehicles with Asbestos. In our study, four out of the 137 vehicles sampled (i.e., 2.9%) of the light- and medium-duty fleet had brake linings with asbestos. Table 3 presents characteristics of the four vehicles found to have asbestos brakes. Two clearly distinguishing factors among the four vehicles determined to have asbestos-containing brake friction material were high mileages and earlier model years. In particular, the average model year of the four vehicles was 1994 compared to the sample fleet average of 1999. Odometer mileages of the four vehicles averaged 148 000 miles, compared to 101 000 miles for the total sample fleet average. From the perspective of mechanical condition, one of the four vehicles required so many repairs (totaling approximately $1300), that it was ultimately rejected from the program and never tested for tailpipe emissions. Another metric of assessing the mechanical condition of the vehicle is the number of VSP18 program emission tests that it fails. Of the three vehicles tested, one failed two tests and two of the vehicles failed one test. A test engineer for the program qualitatively estimated that 60% or more of the vehicles do not fail any of the emission tests.

Regarding vehicle maintenance, three of the four owners had their maintenance performed at a service station or independent garage rather than a dealership. For the fourth vehicle, maintenance was conducted by the owner or a dealership. Maintenance and repair costs at dealerships tend to be significantly higher than service stations or independent repair facilities. In addition, asbestos linings are less expensive than nonasbestos linings[31] and so the owner may have requested less-expensive brakes. In summary, these four vehicles can be characterized as early model, high-mileage, and mechanically compromised, with their owners tending to minimize the cost of maintenance and repairs. Based on high mileage and/or confirmation by vehicle owners, all four vehicles with asbestos-containing brakes were assumed to have had their brakes replaced at least once, thereby indicating a high probability of an aftermarket source of the brake linings.

Although no single characteristic described above would likely serve to distinguish a vehicle with asbestos brake linings compared to one that does not, the ensemble of characteristics nonetheless serves to typify those light- and medium-duty vehicles that do have asbestos brake linings. However, this small sample size of four vehicles does warrant caution in extrapolating these results to a larger fleet. These characteristics are not likely to be useful in predicting if a given vehicle will have asbestos brake linings, since many vehicles may have the above traits, but only a very few of those are likely to have asbestos-containing brake linings.

The lack of asbestos-containing brake linings in the heavy-duty vehicles sampled may be due to the low sample size of 54 and/or the result of heavy-duty brake specifications that preclude the use of asbestos. There is also a possibility of some bias in the heavy-duty brake samples collected, since front tractor brake linings may be of identical composition to the rear tractor brake linings because they typically have the same specifications and are often replaced at the same time with the same brake linings. The same is often true for trailer brakes; when trailer brake linings are replaced, all are typically changed at the same time. There is also a sparse representation regarding the variety of use in the total fleet sampled, with only three buses sampled and many other specialty vehicles not included.

Regulatory Implications. In the mid to late 1980s, brake lining manufacturers began to develop alternatives to asbestos, motivated by litigation and the aforementioned asbestos bans in European countries and an imminent USEPA ban on asbestos use in friction products. However, following the ban enacted by the USEPA in 1989 and the court's subsequent reversal of that ban in 1991,[10,11] auto manufacturers and the aftermarket brake lining industry continued to use asbestos. In 1998, it was estimated that approximately 25% of the light-duty and medium-duty vehicles sold in the U.S. were equipped with OEM drum brakes containing asbestos.[12] At the same time, the aftermarket brake industry in the U.S. was reported as being approximately 10 times the size of the OEM market.[12]

The consensus among automotive trade associations is that no U.S. automotive manufacturers currently use asbestos in OEM brakes, and that no foreign vehicle manufacturers are selling brakes with asbestos in the U.S. market. However, without a federal ban aftermarket providers of brake linings throughout the U.S. are likely to continue to include asbestos-containing linings within the mix of their product offerings. The future trend nationally in the use of asbestos is likely to depend on availability, cost advantage, and the likelihood of a ban on importation and sales. Although our study identified only four vehicles with asbestos-containing brake linings, all four were high mileage vehicles with a high likelihood of aftermarket brake linings, with three of four having linings from the same Canadian aftermarket manufacturer. In late 2010, after completion of our study, California signed into law Senate Bill (SB) 346,[16] which specifies a de mimimis level of 0.1% by weight of toxics in motor vehicle brake friction materials, including asbestiform fibers, as well as compounds of cadmium, chromium(VI), and mercury. This regulation takes effect on January 1, 2014 and essentially bans asbestos and these other toxic compounds in brake lining formulations for vehicles sold in the state. At this time, California appears to be the only state to ban asbestos use in automotive brake linings.

Our sampling program found that only 3% of light- and medium-duty vehicles and 0% of heavy-duty vehicles had brake linings with asbestos, supporting the contention that the U.S. is currently experiencing a downward trend in the use of asbestos in brake linings. Although there have been repeated calls by national and international organizations to implement a worldwide ban on asbestos products, most recently by the Collegium Ramazzini (a nonpartisan international academic society that examines public health issues), no U.S. or worldwide ban appears forthcoming.[32,33] Thus, the monitoring of asbestos use and other toxic materials in brake linings is a prudent course of action. In this context, ongoing sampling programs will be required to assess the prevalence of asbestos and other toxic substances present in the brake dust released from the operation of on-road vehicles, and adherence to state regulation.

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- What abt. checking autoparts shops
- are asb. brakes visually recognizable [illegible]
- identify products [illegible]
and verify OSHA labels
- prepare to enforce new law by surveillance
- should also ban auto gaskets, any idea how common they are [illegible]