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Contribution of Brake Lining Wear to Urban Airborne Asbestos

by

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SUMMARY

A report recently issued by the Office of Toxic Substances of the Environmental Protection Agency reviewed the literature on asbestos emissions and concluded that "the only use of asbestos products which appears to release potentially significant weight units of free-fibers to the general environment is friction material applications." This conclusion is biased toward one report which incorrectly found high asbestos levels in brake debris despite several other reports which showed much lower levels. Further, a defective model was used to predict the urban asbestos concentration. We have reviewed the available literature on the subject to determine the best analytical results. Based on this review, a lead tracer model predicts that the asbestos emitted during braking contributes about 0.08 nanograms per cubic meter of air in New York City, which is 0.4% of typical New York ambient asbestos levels.

INTRODUCTION

A recent report on asbestos prepared for the Office of Toxic Substances of the Environmental Protection Agency(1) has consolidated the literature on the manufacture, use, and environmental effects of asbestos products. This report, by the Syracuse Research Corporation, alleges that friction materials, specifically brake linings, are "the most serious polluter of any of the asbestos products." To arrive at this conclusion, the results from five studies(2-6) which found asbestos concentrations in brake dust of less than 1% were averaged with a single study(7) which reported asbestos contents of 2 to 15%. This result was used in a model to predict the contribution of brakes to urban asbestos levels.

We find fault with three areas of the report. First, the various literature studies were not evaluated in terms of analytical validity although this becomes extremely important for asbestos. Second, the single report which found high asbestos levels was given undue importance in the calculation of brake emission values. Finally, there are serious flaws in the model which result in a gross over-estimation of the amount of asbestos which brakes contribute to urban asbestos levels. In addition, since publication of the Syracuse report, more information has become available on asbestos emissions from brakes. In this report we will reevaluate all available information and develop a revised estimate of the contribution of brakes to urban asbestos levels. We believe that this reevaluation is necessary since the findings of the Syracuse Research Corporation may misdirect future regulatory action by the Environmental Protection Agency.

BACKGROUND

The definition of asbestos is extremely important, particularly since this can affect the choice of an analytical method. Asbestos has been defined as a group of fibrous silicate minerals. The term "asbestos" is not based on chemical composition alone since several different chemical structures are grouped under this title. Rather, the term asbestos also indicates that the structural unit is a fibril, many of which form the asbestos fibers. The fibrous form has the strength and flexibility which make asbestos useful in so many products. Approximately 10% of all the asbestos used in the United States goes into friction materials, principally brake linings, which have a 40 to 60% asbestos content. Therefore, the possibility of asbestos emissions to the ambient air during brake usage has been examined in recent years by several groups. In these studies brake dust has been collected from brake dynamometer systems(3,5,8,9), from brakes on a car during normal driving(4), and from the brake assemblies of cars(2-4,6,7,9). In each case, attempts were made to determine the asbestos content of the collected brake dust, but the results range over several orders of magnitude. The principal cause of the large variability in results is the choice of analytical method to quantify the asbestos. Since the asbestos content of brake linings is about 50% and the asbestos content of the wear debris is far lower, some of the asbestos must either have separated from the debris or have been degraded to another material. One study(8) has shown that the chemical constituents of asbestos (a magnesium silicate) are preserved in the wear debris, which means that selective separation of the asbestos did not occur.

More specifically, it is known that asbestos dehydroxylates at 680°C and can be converted to nonfibrous powder at 860°C. Such temperatures are apparently attained at the contact points in asbestos composites during braking, even though the bulk temperatures in the brake components are usually much lower(4). Although attempts to identify specific mineral structures in brake dust, such as forsterite, have been inconclusive(4,8), the degradation products must be a combination of nonfibrous magnesium silicates. From the above description of asbestos, we know that these nonfibrous minerals can no longer be classified as asbestos. Therefore, the analytical method in studies of brake emissions must be able to differentiate between fibrous and nonfibrous material. A recent study of analytical methods for asbestos(10) stated the following:

> "X-ray diffraction, X-ray fluorescence, differential thermal analysis, infrared spectroscopy, neutron activation analysis, and atomic absorption cannot distinguish fibrous from nonfibrous minerals and cannot give fiber size-distribution data."

Therefore, the only valid analytical method for determining low asbestos concentrations is microscopy. With these concerns about analysis in mind, the various studies of asbestos emissions from brakes will now be evaluated.

REPORTS OF LESS THAN 1% ASBESTOS

The simplest method of obtaining a sample of brake wear material is to collect dust retained in the wheel. Both Hatch(6), and Hickish and Knight(2), used this method and found the asbestos content of the retained dust to be less than 1%. These papers, which addressed the industrial hygiene concerns of brake asbestos, most likely used optical microscopy which is insensitive to fibers smaller than a few micrometers in length. However, Lynch(3) had already examined retained brake dust using electron microscopy and had also concluded that the asbestos content was less than 1%. These early studies clearly showed that most of the asbestos in brake linings is decomposed by the wear processes which occur in automobile braking.

Brake wear material can also be obtained by collecting airborne particulate samples in the vicinity of a brake dynamometer. This is advantageous since the main interest is in the material emitted into the air from brakes, and it is possible that emitted dust could have a composition different from the composition of the dust which is retained in the wheel. Rowson(8), in a dynamometer study, examined the emitted dust by electron microscopy. Several microscope fields were examined and only one fibril was found. Rowson estimated an upper limit for the asbestos content of 0.5%. It should be noted that all of the results discussed so far have been reported as upper limits based on microscopic examination.

Anderson et al.(5) also collected airborne particles near a brake dynamometer. They sized fibers according to length and diameter to arrive at an asbestos mass from which they determined that asbestos comprised only 0.0049% of the emitted brake debris. We have also collected airborne particle samples from a brake dynamometer with the test brake enclosed in a tube purged by clean air(11,12). The asbestos content in our studies ranged from 0.001 to 0.19% with an average of 0.03%. These values were determined by carefully counting and sizing the asbestos fibers with a transmission electron microscope. Our studies were carried out with filter samples containing a weighed amount of total dust.

Jacko and DuCharme(4) sampled brake emissions on board an automobile. They enclosed the brake with a shroud from which airborne particulate was collected on a filter. Three vehicle tests were run on different brake sets and the average asbestos concentrations found were 0.07, 0.25, and 0.38%. These values were also obtained using transmission electron microscopy to count and size the asbestos fibers.

THE MOUNT SINAI REPORT

All the studies mentioned so far agree that brake wear results in dust which has an asbestos content less than 1%. The only report indicating higher asbestos levels in brake dust is a study at the Mount Sinai School of Medicine by Rohl et al.(7) in which 10 samples of dust recovered from wheels were analyzed by X-ray diffraction. This technique, which was not used by other workers, yielded compositions ranging from 2 to 15% asbestos. Obviously, the results of this study are anomalous in comparison with the other estimates. The difference seems to be due to the analysis method. The choice of X-ray diffraction is surprising when it appears to be generally agreed that X-ray diffraction is not useful for detecting small amounts of asbestos in mixtures(13,14) and when other researchers have examined brake debris with X-ray diffraction and have not found any asbestos(4,8,15). It is possible for nonfibrous asbestos-degradation products to yield similar diffraction patterns and to be mistakenly identified as asbestos(4,13). It is interesting that when Rohl et al.(7) examined brake samples by electron microscopy, they concluded that "the presence of chrysotile asbestos in the ten dust samples was further verified by transmission electron microscopy . . . It's frequency of occurrence was consistent with, but lower than the quantitative determination made by X-ray diffraction analysis." However, no quantitation was attempted by microscopy.

As corroboration of Rohl's work, the Syracuse report also cites a publication by Alste et al.(16). Alste examined brake wear debris which was brushed from a worn brake lining. Asbestos fibers were identified by electron microscopy, but no quantitative estimates were made. The Alste paper concluded that since the crystal structure of the asbestos in the wear debris was the same as the crystal structure in unused brake lining, the main effect of braking was to separate the asbestos fibers and to reduce their length. However, while these results show that some of the asbestos survives in brakes, they have little to do with measuring how much of the asbestos survives. Anyone who examines ashed brake debris under a microscope can readily see that most of the inorganic material is nonfibrous. Hence, the observations by Alste et al. obviously do not corroborate the study by Rohl et al.

Similar conclusions were drawn by Seshan and Smith(15) who found unaltered asbestos as well as deformed fibers, which they claim as support for the conclusions of Rohl and Alste. Once again, Seshan and Smith proved only that some asbestos survives the braking process, an issue which has not been in question since Lynch's publication in 1968. Instead the low level of asbestos survival was reaffirmed because Seshan and Smith could find no asbestos in the brake dust by optical microscopy or by X-ray diffraction.

BRAKE ASBESTOS IN URBAN AIR

As part of the report to the Environmental Protection Agency, the Syracuse Research Corporation estimated the contribution of brake linings to the ambient asbestos levels in New York City. Based on Jacko's report(4), nationwide airborne asbestos emissions from brakes are 2.3×10^6 grams per year, whereas based on Rohl's report(7) they are 50×10^6 grams per year. This difference results entirely from the discrepancy in the reported asbestos content of brake debris. The Syracuse report assumed an intermediate value of 9.1×10^6 grams per year, and then apportioned the brake asbestos emissions in New York City on the basis of its population as a fraction of the national population. If one day's brake emissions were uniformly dispersed over the area of the city with a mixing height of 300 meters, the ambient air concentration of asbestos due to brakes would be 3.7 ng/m^3. The report then states that this concentration is of the same order of magnitude as the reported 11 to 60 ng/m^3 typical of New York City air. This approximation would seem to suggest that brake lining wear was a major source of asbestos in New York City.

We believe that there are two main problems with this calculation. First, the questionable data from Rohl et al. greatly influenced the average emission rate. Second, in the model, the air is assumed to be renewed only once every 24 hours. This would result from an annual average wind speed of approximately 0.3 m/s. The actual mean wind speed in New York City is over 4 m/s(17). Even Los Angeles, which is noted for stagnant conditions, has an average wind speed of 3.3 m/s. Therefore, this model assumes an extremely stagnant situation with correspondingly high concentrations for the entire year. Because of these two problems, the result of the calculation is an erroneously high estimate of the ambient air concentration of asbestos due to brakes.

A better approximation of urban asbestos levels can be obtained by revising the brake emission estimate and inserting these in a more accurate model. The various reports of the asbestos content of brake debris are summarized in Table 1. To obtain the best quantitative measure of asbestos in brake debris, we will consider only the three studies which used transmission electron microscopy(4,5,9). The three studies report average asbestos contents of 0.2%(4), 0.03%(9), and 0.005%(5). Since we have studied several brake linings and test conditions and our results encompass the entire range (0.001 to 0.19%), we conclude our average value, i.e., 0.03%, is the most representative value for the asbestos content of brake-wear emissions. Based on this 0.03% value, we have reported total asbestos emissions of 4.9×10^6 g/yr which is twice Jacko's estimate of 2.3×10^6 g/yr. Although our asbestos concentrations in brake debris were lower than the values reported by Jacko, we found that a much larger fraction of the total wear debris was emitted as airborne dust which more than compensated for the lower asbestos content.

The most reliable estimate of the amount of brake-wear asbestos in New York City air can be obtained by using a simple lead tracer model. Since vehicles account for most of the lead in urban air, and since both the per mile emission rate of lead and typical New York City lead concentrations are known, this simple model needs only the vehicle emission rate of any other emitted material to predict its urban air concentration resulting from vehicles. The model will be applied to the situation which existed in the early 1970's when most vehicles used leaded gasoline.

The total nationwide asbestos emission of 4.9×10^6 g/yr can be written as 4.4 micrograms/mile/car assuming that there are 114 million automobiles in the United states each traveling 10 000 miles/year. Based on a lead emission rate of 108 mg/mile(18), of which 60% remains airborne, and a typical New York City air concentration of 2 micrograms per cubic meter(19,20) of lead, the tracer model predicts that the same urban air would have contained 0.08 ng/m^3 of asbestos from cars using the 4.4 micrograms per mile emission rate. The same relationship applies to any other site where lead was measured. The model can be adjusted for the reduction in the amount of leaded gasoline used currently, but the projected urban air level of asbestos from brakes does not change.

Brake-wear asbestos levels of 0.08 ng/m^3 represent only 0.4% of the 20 ng/m^3 of asbestos reported in a number of locations in New York City(21). It is expected that this conclusion will hold in other cities as well since they have similar traffic patterns and air renewal rates. Similar quarterly average values of urban asbestos(22) which have been reported must likewise be dominated by nonbrake asbestos sources.

CONCLUSIONS

Considerable research has been devoted to determining the fraction of the asbestos which survives the braking process. The reported asbestos content of the worn-off dust encompasses an extremely large range, from 0.005% to 15%. The recent Syracuse Research Corporation report to the Environmental Protection Agency evaluated the available literature to determine the importance of brake emissions and concluded that brakes are an important contributor to ambient asbestos levels. We have shown that this conclusion is incorrect because it is heavily biased by the one data set obtained by X-ray diffraction techniques which are inappropriate for determining asbestos and on a model that grossly overestimates the expected brake-wear asbestos in urban air. We have reviewed the available literature on the subject in terms of collection and analytical methodology. Using the most reliable results for the asbestos content of brake debris and the lead tracer model, we found that the contribution of brakes to urban asbestos levels can only account for about 0.4% of the asbestos in New York City air.

REFERENCES

1. W. M. Meylan, P. H. Howard, S. S. Lande, and A. Hanchett, Syracuse Research Corporation, as EPA 68-01-3224, August 1978.

2. D. E. Hickish and K. L. Knight, Ann. of Occup. Hyg. 13, 17 (1970).

3. J. R. Lynch, J. Air Pollut. Control Assoc. 18, 824 (1968).

4. M. G. Jacko and R. T. DuCharme, Bendix Research Laboratories, Report 68-04-0020, March 1973.

5. A. E. Anderson, R. L. Gealer, R. C. McCune, and J. W. Sprys, SAE Trans. 82, 1832 (1973).

6. D. Hatch, Ann. of Occup. Hyg. 13, 25 (1970).

7. A. N. Rohl, A. M. Langer, M. S. Wolff, and I. Weisman, Environ. Res. 12, 110 (1976).

8. D. M. Rowson, Wear 47, 315 (1978).

9. J. L. Muhlbaier and R. L. Williams, General Motors Research Laboratories, Publication GMR-3435, November 1980.

10. A. V. Samudra, F. C. Bock, C. F. Harwood, and J. D. Stockham, IIT Research Institute, as EPA 600-2-78-038, June 1978.

11. R. L. Williams, General Motors Research Laboratories, Publication GMR-3447, November 1980.

12. R. L. Williams and J. L. Muhlbaier, General Motors Research Laboratories, Publication GMR-3434, November 1980.

13. J. C. Haartz, B. A. Lange, R. G. Draftz, and R. F. Scholl, in National Bureau of Standards Special Publication 506, November 1978, p. 295.

14. H. D. Stanley, in National Bureau of Standards Special Publication 506, November 1978, p. 325.

15. K. Seshan and G. R. Smith, in 35th Annual Proceedings of Electron Microscopy Society of America, G. W. Bailey, Ed. (Boston, 1977).

16. J. Alste, D. Watson, and J. Bagg, Atmos. Environ. 10, 583 (1976).

17. Climates of the States, Vol. 1 (Water Information Center, Inc., Manhasset Isle, Port Washington, NY, 1974), p. 271, 272.

18. S. H. Cadle and G. J. Nebel, in Introduction to Environmental Toxicology, F. E. Guthrie and J. J. Perry, Eds. (Elsevier, NY, 1980), p. 420-432.

19. J. M. Colucci, C. R. Begeman, and K. Kumler, General Motors Research Laboratories, Publication GMR-773, June 1968.

20. M. T. Kleinman, B. S. Paternack, M. Eisenbud, T. J. Kneip, Environ. Sci. Technol. 14, 62 (1980).

21. I. J. Selikoff, W. J. Nicholson, and A. M. Langer, Arch. Environ. Health 25, 1 (1972).

22. R. J. Thompson, in National Bureau of Standards Special Publication 506, November 1978, p. 355.

Table 1. A Summary of Literature Reports on the Asbestos Content of Brake-Wear Debris

Author	Source of Sample	Analysis Method	% Asbestos Found
Lynch(3)	Brake dust and brake dynamometer tests	Electron microscopy	<1
Hickish and Knight(2)	Brake drum dust	Optical microscopy	<1
Hatch(6)	Air sampling during brake drum blowout	Optical microscopy	∿1
Jacko and DuCharme(4)	Operating auto tests	TEM	0.2
Anderson et al.(5)	Brake dynamometer tests	TEM	0.0049
Rohl et al.(7)	Brake dust	X-ray diffraction	2 to 15
Rowson(8)	Brake dynamometer tests	Electron microscopy	<0.5
Muhlbaier and Williams(9)	Brake dynamometer tests	TEM	0.03