emissions can be approximated from the airborne asbestos emission rate of 3.82 µg/car mile, resulting in 11.9 µg/car mile. Considering these close results, we can infer that the asbestos emissions from automobiles contribute only a small portion to the total national level.

The total number of airborne asbestos fibers emitted in this study was 3.0×10^7 fibers/disc-brake mile; the fibers averaged 0.59 µm in length. There were about 26,000 fibers/ng of asbestos. Muhlbaier and Williams' (3) reported compatible values, showing a median fiber length of 0.5 µm and fiber density of 90,000 fibers/ng of asbestos.

The results of these three typical investigations are summarized in Table 5. Other investigations also used an electron microscope for asbestos analysis. Anderson et al. (13) used a brake dynamometer and concluded that particulates emitted from automobile brakes contained only 0.005% asbestos. Rowson (14) collected airborne particles from a shrouded brake assembly mounted on an inertia dynamometer and measured an asbestos concentration less than 0.5% in wear debris. All these reports show the asbestos concentration to be less than 0.5%.

CONTRIBUTION OF BRAKE ASBESTOS IN URBAN AIR - The RBC's and the frequency distribution used to measure particulate and asbestos emissions from automobile brakes in the current study were based on inner-city driving. Because most brake emissions are expected in urban areas, it would be appropriate to estimate automobile brake contributions to the asbestos level in urban air by using meteorological models or surrogate models. These models can determine the maximum possible contribution of brake emissions to the ambient asbestos level, from which the corresponding health effect can be inferred.

Bradow (15) used dispersion models developed as a result of the U.S. Environmental Protection Agency's Regional Air Pollution Study to find automobile exhaust particulate contributions for the city of St. Louis, MO. In the calculations, the central city area had a maximum annual average concentration of 13 $\mu g/m^3$ for the vehicle particulate emission rate of 0.195 g/mile. For the same models, the contribution of asbestos emissions from automobiles in the current study is a maximum of 0.25 ng/m^3 for the emission rate of 3.8 µg/car mile. Based on the measured value for the number of fibers per unit mass (26,000 fibers/ng), the contribution is equivalent to 6500 $fibers/m^3$. The automobile asbestos emissions in St. Louis can be similiar to those for other large cities in the United States. From the data in Reference 1, the ambient asbestos concentrations in large cities (Dayton, OH, and Frankfort, KY, are excluded) vary from 1.6 to 200 ng/m^3, averaging approximately 20 ng/m^3. Therefore, the maximum contribution of asbestos from automobiles ranges from 0.13 to 16% for large cities; the average maximum contribution is about 1.3%.

Williams and Muhlbaier (4) estimated the contribution of brake wear asbestos in New York City by using a lead tracer model. In this model, the vehicle emission was assumed to contribute to the ambient air at the same ratio as lead emissions. In their study, a lead emission rate from a car was found to be 108 ng/mile, of which 60% remains airborne with a typical air concentration of 2 $\mu g/m^3$-car. Using the same ratios, we found an asbestos contribution of 0.12 ng/m^3 for an emission rate of 3.8 µg/car mile. This value is close to that obtained by Williams and Muhlbaier (4). Since the asbestos concentration of ambient air in New York City ranges from 8 to 41 ng/m^3 (1), the contribution from automobile brakes represents only 0.3 to 1.5%.

Considering the results of the dispersion and lead trace models, the maximum asbestos contribution from automobiles to the ambient air in cities is 0.25 ng/m^3, and ranges from < 1 to 16%.

SUMMARY AND CONCLUSIONS

RBC's and their frequency distribution were found by statistically analyzing downtown city driving in Raleigh, NC. The particulate as well as asbestos emissions from automobile brakes were characterized by simulating these RBC's on a computer-controlled dynamometer.

Average total particulate emissions (deposited plus airborne) were approximately 12 mg/disc-brake mile, of which 3.8 mg or 32% remained airborne. The average aerodynamic diameter of airborne particulates was 3.7 µm. Based on the 1.6:1.1 wear ratio between disc and drum brakes, the estimated airborne particulate emission rate was 12.8 mg/car mile.

Airborne particulates contained 0.018% asbestos fibers, resulting in an asbestos emission rate of 1.1 µg/disc-brake mile or 3.8 µg/car mile for the same disc to drum brake wear ratio. The average length of single fibers and fiber bundles was about 0.6 µm.

From dispersion models for the city of St. Louis, MO, the maximum contribution of asbestos emissions from automobiles to the ambient air was 0.25 ng/m^3 or 6500 $fibers/m^3$. Assuming other big cities have similar dispersion and emission factors, the contribution of automobile brakes varied from 0.13% to 16%, averaging 1.3%.

Results from this investigation agree well with those of Williams and Muhlbaier (4). Judging from the current and previous investigations using electron microscope analysis, asbestos emissions from automobile brakes contribute little to the ambient asbestos level compared to other sources.