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Airborne Asbestos Concentrations During Spray-Buffing of Resilient Floor Tile

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A study was conducted to determine the level of airborne asbestos concentrations during routine spray-buffing of asbestos-containing floor tiles at 17 schools in northern, central, and southern New Jersey. Although the schools selected do not represent a statistical random sample, they do represent a cross section of floor conditions and floor-care maintenance practices. Increased airborne asbestos levels during spray-buffing were measured at 12 of the 17 schools. The increase was statistically significant at 7 of the 17 schools. Overall, the mean relative increase in airborne asbestos concentrations during spray-buffing with the high-speed machines (1000 to 1500 rpm) was statistically significantly higher than that during buffing with low-speed machines (175 to 330 rpm). Machine speed appeared to have a significant effect on the structure morphology of the airborne asbestos structures generated during spray-buffing. This study demonstrates that routine spray-buffing of asbestos-containing resilient floor tile can be a source of asbestos-containing particles in building air. Edwards, A.; Kominsky, J.R.; Freyberg, R.W.: Airborne Asbestos Concentrations During Spray-Buffing of Resilient Floor Tile. Appl. Occup. Environ. Hyg. 9(2):132–138; 1994.

Introduction

Although no longer manufactured in the United States, asbestos-containing resilient floor tiles are installed in residential dwellings, institutions, commercial and public office buildings, and industrial facilities. The organic matrix in floor tiles may be either asphalt or polyvinyl chloride, and their dimensions are either 9 in. × 9 in. or 12 in. × 12 in. The asbestos in nearly all floor tiles is chrysotile, which is dispersed throughout the thickness of the tile. Although these floor tiles are considered nonfriable, the frictional forces exerted on these materials during routine floor-care maintenance operations (e.g., wet scrubbing and stripping) can generate asbestos-containing particles.[1]

Little data are available for evaluating the extent of asbestos structures released during other floor-care maintenance procedures, such as spray-buffing. Spray-buffing is the restorative maintenance of a previously polished floor by use of a suitable floor-polishing machine immediately after the surface has been mist-sprayed with an appropriate product whereby the wet application is buffed to dryness.[2] The levels of airborne asbestos structures released during spray-buffing could be higher than those during wet stripping,[1] especially if the floor has been poorly maintained (i.e., minimal wax layer), is worn, or is otherwise damaged.

A study was conducted to evaluate airborne asbestos concentrations during routine spray-buffing of asbestos-containing floor tile.[3] The primary objectives of this study were 1) to determine the airborne asbestos concentrations during routine spray-buffing of asbestos-containing resilient floor tile in a cross section of schools in northern, central, and southern New Jersey, and 2) to compare the fiber concentrations measured by phase contrast microscopy (PCM) during routine spray-buffing of asbestos-containing floor tile with the Occupational Safety and Health Administration (OSHA) action level of 0.1 fiber/cm^3 (f/cm^3) of air, 8-hour time-weighted average (TWA).

Study Sites

This study was conducted at 17 schools in northern, central, and southern New Jersey. The selected schools were distributed among eight school districts. Although these schools do not represent a statistical random sample, they do represent a cross section of floor conditions and floor-care maintenance operations. The schools selected for study were prescreened to establish that the resilient floor tile contained more than one percent asbestos. Access to the schools was coordinated directly by the New Jersey Department of Health-Environmental Health Service (NJDOH-EHS). The NJDOH-EHS collected bulk samples of all floor tiles, documented floor-care practices, floor conditions, and characteristics of the floor-buffing equipment and materials in each school, as well as other variables that might have an impact on the release of asbestos structures.

In all of the schools, the existing custodial staff performed the floor-care maintenance operations. The floors were prepared (i.e., dry and/or wet-mopped) and spray-buffed in accordance with established practices and procedures at the respective schools.

Sampling Strategy

The first study objective was to determine whether airborne asbestos concentrations increase during the spray-buffing of floor tile. This was addressed by collecting air samples before and during floor-buffing operations. A maximum of two distinct areas were tested in each school studied. Immediately before spray-buffing operations began, three baseline ("before spray-buffing"), fixed-station, area air samples were collected in each test area under normal building conditions (i.e., no intentional air disturbance beyond that attributable to normal occupancy activity in the area). Three personal breathing zone samples were collected on the machine operator during spray-buffing operations for comparison with the baseline samples. The three baseline area samples and three personal breathing zone samples were analyzed by transmission electron microscopy (TEM).

The second study objective was to compare total fiber concentrations during buffing operations with the OSHA action level of 0.1 f/cm^3, 8-hour TWA (29 CFR 1910.1001). This was achieved by collecting one sample in the breathing zone of the machine operator during the spray-buffing in each area. These samples were analyzed by PCM.

Bulk samples of each type of floor tile present in each school were collected. The samples were collected to determine the percentage and type of asbestos in the floor tile.

Sampling Methods

Fixed-Station Area Air Samples

The baseline, fixed-station, area air samples were collected on open-face, 25-mm-diameter, 0.45-μm-pore-size, mixed cellulose ester (MCE) filters with a 5-μm-pore-size MCE diffusing filter and a cellulose support pad contained in a three-piece cassette. The filter cassettes were positioned on tripods approximately 5 feet above the floor, with the filter face at a 45° angle toward the floor. The filter assembly was attached to a calibrated, electric-powered 1/6-horsepower vacuum pump operating at a flow rate of approximately 9 L/min. Air volumes ranged from 564 to 916 L.

Personal Breathing Zone Air Samples

Personal breathing zone air samples were collected on open-face, 25-mm-diameter, 0.45-μm-pore-size MCE filters with a 5-μm-pore-size MCE diffusing filter and a cellulose support pad contained in a three-piece cassette without a 50-mm extension cowl. Personal breathing zone samples were also collected on a 25-mm-diameter, 0.8-μm-pore-size MCE filter, and a cellulose support pad contained in a three-piece cassette with a 50-mm conductive extension cowl. Each type of filter cassette (including three 0.45-μm-pore-size filter assemblies and one 0.8-μm-pore-size filter assembly) was clipped to the machine operators' shirt lapel. The cassettes were attached to approximately 50 ll of Tygon® tubing connected to a calibrated, electric-powered 1/6-horsepower vacuum pump operating at a flow rate of approximately 9 L/min. The pumps were positioned in a wagon to facilitate movement with the buffing-machine operator. The use of high-volume air sampling pumps was necessary to achieve the target air volume of 600 L in the time required to spray-buff the test area. Air volumes ranged from 617 to 970 L.

Bulk Floor Tile Samples

Bulk samples were collected of each type of floor tile present in each school. Each sample consisted of a 2-in. × 2-in. section of floor tile. A 2-in. × 2-in. template was used to delineate the area on the floor tile. A hammer and wood chisel were used to remove the tile, which was then placed in a labeled plastic bag. Prior to analyzing each of the bulk floor tile samples, the mastic was removed from the specimen by the microscopist.

Analytical Methods

Air Samples

The 0.45-μm-pore-size MCE filters were prepared and analyzed in accordance with the nonmandatory TEM method specified in the Asbestos Hazard Emergency Response Act (AHERA) Final Rule (October 30, 1987; 40 CFR Part 763). In addition, the specific length and width of each structure were measured and recorded. A sufficient number of grid openings were analyzed to ensure an analytical sensitivity (the concentration represented by the finding of a single structure) of no greater than 0.005 asbestos structure per cubic centimeter of air sampled (40 CFR 763), unless the degree of loading made this impractical. Samples were analyzed according to AHERA nonmandatory TEM counting rules except that some grid openings with greater than 25 percent particulate matter were analyzed. AHERA specifies that grid openings covered with greater than 25 percent particulate matter should not be analyzed. This exception to the AHERA nonmandatory method was made because of the research nature of this study to obtain additional information.

Each of the 0.8-μm-pore-size MCE membrane filters was analyzed by PCM. These samples were prepared and analyzed according to the NIOSH 7400 protocol (Revision 3, June 5, 1989, NIOSH Manual of Analytical Methods). All fibers with a 3:1 (or greater) length-to-width ratio and longer than 5 μm were counted using the A counting rules. The limit of detection was approximately 0.01 f/cm^3 of air sampled. Although the NIOSH 7400 protocol specifies to reject a graticule field if an agglomerate covers approximately one-sixth or more of the field, an exception to this rule was made on some heavily loaded samples.

Bulk Floor Tile Samples

The type and percentage of asbestos in the floor tile were determined by polarized light microscopy (PLM) analysis in accordance with the U.S. Environmental Protection Agency test method "Interim Method for Determination of Asbestos in Bulk Insulation Samples" (EPA 600/M4-82-020). A confirmatory analysis was performed on floor tile from eight of the 17 schools. The samples were analyzed by TEM in accordance with Chatfield's Method (SOP-1988-02, Revision No. 1: Analysis of Resilient Floor Tile).

Statistical Methods

Descriptive statistics were calculated for each school and each area within a school. These descriptive statistics included the sample size; arithmetic mean, minimum, and maximum airborne asbestos concentrations; and the arithmetic standard deviation. All estimated concentrations were based on the number of asbestos structures counted. If no asbestos structures were counted in a sample, a value of 0 s/cm³ was used as the measured concentration. Results of the quality assurance samples were not included in the statistical analysis of the data.

A two-factor analysis of variance (ANOVA) was used to compare airborne asbestos concentrations before and during floor buffing. Each school was considered separately. The experimental factors in the ANOVA analysis were the sample period (baseline, during) and area within a school (A or B). If only one area was studied at a school, the analysis was reduced to a one-factor ANOVA, which is equivalent to a Student's t-test.

The natural logarithm of each measured concentration was used in the ANOVA. This transformation was used to make variances more equal and to provide data that are better approximated by a normal distribution. This is equivalent to assuming that the data follow a lognormal distribution. If one or more samples showed a measured concentration of 0 s/cm³ at a given school, the transformation $\ln(x + 0.002)$, where x is the measured airborne asbestos concentration, was applied to each measurement before the ANOVA was performed. The constant 0.002 was chosen to be smaller than the analytical sensitivity for these measurements and was added to all values (before and during spray-buffing) at that school so the comparison would not be biased. The log transformation was used only for the ANOVA tests; it was not used for any other part of the data analysis (e.g., data graphs or descriptive statistics). All statistical comparisons were performed at the 0.05 level of significance.

TABLE I. Characteristics of Floor Buffing Equipment and Materials

Site	Machine Speed (rpm)	Machine Manufacturer	Pad Color	Pad Manufacture	Polish Used mL/ft²	Solids in Polish (%)
1A	1000	Kent	Red[A]	Norton	1.92	Confidential
1B	1000	Kent	Red[A]	Norton	1.28	Confidential
2A	175	Hild	Red	Glit	0.28	6.3
3A	175	Hild	Red	Norton	0.43	6.3
3B	175	Hild	Red	Norton	0.58	6.3
4A	175	Clark	Red	Glit	0.53	Confidential
5A	1500	Mastercraft	White	Glit	0.14	Confidential
6A	1500	Floorcraft	White	3M	0.20	6.3
6B	1500	Floorcraft	White	3M	0.30	6.3
7A	1100	Hild	White	3M	0.44	9.5–10.5
7B	1100	Hild	White	3M	0.44	9.5–10.5
8A	300	Hild	Red	3M	0.25	Confidential
8B	300	Hild	Red	3M	0.15	Confidential
9A	300	Advance	Red	3M	0.33	Confidential
10A	1500	Tornado	White	3M	0.13	5
10B	1500	Tornado	White	3M	0.14	5
11A	330	Tornado	White	Microtron	0.09	5
11B	330	Tornado	White	Microtron	0.02	5
12A	330	Tornado	White	Glit	0.15	5
12B	330	Tornado	White	Glit	0.07	5
13A	330	Tornado	Green[B]	Norton	0.09	5
13B	330	Tornado	Green[B]	Norton	0.14	5
14A	175	Kent	White	Glit	0.32	5
15A	330	Tornado	White	3M	0.11	5
16A	175	Hild	White	Norton	0.33	Confidential
16B	175	Hild	White	Norton	0.26	Confidential
17A	175	Kent	Red	Microtron	0.13	Confidential
17B	175	Kent	Red	Microtron	0.18	Confidential

[A]Designed for low-speed buffing machines.
[B]Designed for scrubbing and stripping applications.

Results and Discussions

Study-Site Characteristics

Resilient Floor Tile

The resilient flooring in the 28 study sites (representing 17 schools) included mostly 9-in. × 9-in. tiles and some 12-in. × 12-in. tiles. Although the asbestos content of the tiles ranged from 1 to 38 percent, the content of most of the tiles exceeded 10 percent. The areas that were spray-buffed ranged from 727 to 3386 square feet; the average area was approximately 2150 square feet. Any floor areas with damaged (e.g., broken) or missing tiles were isolated to prevent their contact with the buffing machine.

Floor Care Maintenance Practices

The floors were dry- and/or wet-mopped before they were spray-buffed. All of the schools dry-mopped the floors and nine of the schools both dry- and wet-mopped the floors. The floors are typically spray-buffed once a year; however, some schools spray-buffed the floors one to three times each week.

Buffing Equipment and Materials

Table I presents the characteristics of the buffing equipment (e.g., machine speed) and materials (e.g., buffing pad color) used. Twelve of the schools used buffing machines operating at 1000 to 1500 rpm and five used buffing machines operating at 175 to 330 rpm. The appropriate buffing pad (i.e., a white pad with high-speed machines and a red pad with low-speed machines) was used at all of the schools except two. The two exceptions were at School No. 1 where a red pad was used with a high-speed machine, and at School No. 13 where a green pad (designed for heavy scrubbing and light stripping applications) was used with a low-speed machine.

Airborne Asbestos Concentrations Before and During Spray-Buffing

Three samples were collected before and three during routine spray-buffing of asbestos-containing floor tile in each area within a school. Table II presents the descriptive statistics (i.e., mean, minimum, maximum, and standard deviation) separately for each school/area combination and each sampling period (i.e., before and during spray-buffing).

TABLE II. Summary of Airborne Asbestos Concentrations Measured by TEM Before and During Spray-Buffing of Floor Tile

	Asbestos Concentration (s/cm³) (n = 3)							
	Before Spray-Buffing				During Spray-Buffing			
Site	Mean	Minimum	Maximum	Standard Deviation	Mean	Minimum	Maximum	Standard Deviation
1A	0.004	0[A]	0.009	0.005	0.014	0.010	0.019	0.005
1B	0.001	0	0.005	0.003	0.013	0.005	0.019	0.007
2A	0.006	0	0.010	0.006	0.003	0	0.005	0.003
3A	0.001	0	0.005	0.003	0.011	0	0.025	0.013
3B	0	0	0	0	0.003	0	0.009	0.005
4A[B]	0	0	0	0	0	0	0	0
5A	0.009	0.005	0.014	0.005	0.107	0.088	0.123	0.018
6A	0.030	0	0.076	0.040	0.163	0.065	0.302	0.123
6B	0.029	0.015	0.054	0.021	0.205	0.137	0.291	0.078
7A	0.003	0	0.010	0.006	0.145	0.097	0.179	0.043
7B	0.008	0.005	0.014	0.005	0.414	0.379	0.464	0.044
8A	0.011	0.005	0.020	0.008	0.025	0.015	0.030	0.009
8B[C]	0.041	0	0.103	0.055	—	—	—	—
9A	0.010	0	0.020	0.010	0.003	0	0.009	0.005
10A	0.086	0	0.254	0.145	0.067	0.033	0.094	0.031
10B	0.038	0.030	0.045	0.008	0.032	0.029	0.035	0.003
11A	0.033	0.020	0.054	0.018	0.056	0.015	0.097	0.058
11B	0.029	0.005	0.069	0.034	0.077	0.067	0.090	0.012
12A	0.012	0.009	0.014	0.003	0.067	0.043	0.113	0.039
12B	0.065	0.029	0.113	0.043	0.096	0.062	0.151	0.048
13A	0.015	0	0.040	0.022	0.082	0.015	0.206	0.040
13B	0.194	0.051	0.390	0.175	0.290	0.225	0.329	0.057
14A	0.006	0.005	0.010	0.003	0.052	0.020	0.087	0.034
15A	0.094	0.058	0.126	0.034	0.151	0.102	0.216	0.059
16A	0.001	0	0.005	0.003	0.001	0	0.004	0.002
16B	0.003	0	0.005	0.003	0	0	0	0
17A	0.001	0	0.005	0.003	0.056	0.052	0.059	0.004
17B	0.050	0.024	0.065	0.023	0.114	0.035	0.189	0.07

[A]Concentrations for samples where no asbestos structures were counted are reported as 0 s/cm³. The analytical sensitivity for these samples was less than or equal to 0.005 s/cm³.
[B]Summary statistics are based on two samples (n = 2). Both samples showed levels of 0 s/cm³, hence, all table entries are zero for this site.
[C]The samples collected during spray-buffing were too heavily loaded with particulate to count.

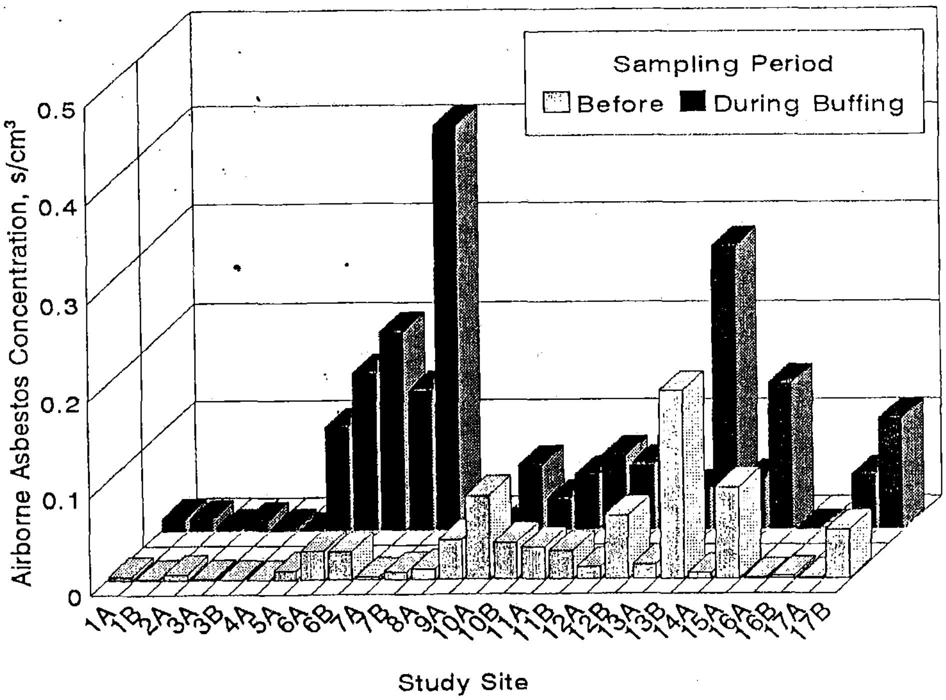

FIGURE 1. Average airborne asbestos concentrations before and during spray-buffing of asbestos-containing resilient floor tile (as measured by TEM).

Figure 1 shows the average airborne asbestos concentrations at each area before and during spray-buffing.

Increased airborne asbestos levels during spray-buffing were noted at 12 of the 17 schools. The increase was statistically significant at seven of these schools (Nos. 1, 5, 6, 7, 12, 14, and 17). Compared with baseline measurements taken before spray-buffing, airborne asbestos concentrations were qualitatively the same or lower during spray-buffing at the remaining five schools (Nos. 2, 4, 9, 10, and 16).

Overall, the mean relative increase (i.e., the average increase as measured by the ratio of the mean concentration during buffing to the mean concentration before buffing) in airborne asbestos concentrations during spray-buffing with the high-speed machines (1000 to 1500 rpm) was significantly higher ($p = 0.0326$) than the increase during spray-buffing with the low-speed machines (175 to 330 rpm). On average, airborne asbestos concentrations were approximately five times higher during spray-buffing than before spray-buffing with the higher speed machines, whereas spray-buffing with the lower-speed machines showed a twofold increase during buffing than before.

TABLE III. Total Fiber Concentrations During Spray-Buffing of Resilient Floor Tile (as Measured by PCM)

Site	Total Fiber Concentration (f/cm³)	Site	Total Fiber Concentration (f/cm³)
1A	0.033	10A	0.133
1B	0.034	10B	0.061
2A	0.078	11A	0.295
3A	0.077	11B	0.065
3B	0.076	12A	0.067
4A	0.024	12B	0.070
5A*	—	13A	0.085
6A	0.130	13B	0.220
6B*	—	14A	0.042
7A	0.048	15A	0.076
7B*	—	16A	0.080
8A*	—	16B	0.104
8B*	—	17A	0.027
9A	0.030	17B	0.055

*Samples were too heavily loaded with particulate to count.

Baseline Airborne Asbestos Concentrations Based on Frequency of Spray-Buffing

Spray-buffing is routinely performed (one or more times weekly) at seven schools, but less frequently (once per month to per year) at the remaining ten schools. The mean airborne asbestos concentrations measured before spray-buffing at the schools in which spray-buffing is routinely performed (0.035 structures per cubic centimeter) was significantly greater ($p = 0.0004$) than the mean baseline concentration measured at schools in which spray-buffing is performed less frequently (0.007 s/cm³).

Personal Breathing Zone Concentrations of Total Fibers

Table III presents total fiber concentrations measured in the machine operator's breathing zone during spray buffing, as determined by PCM. The actual time spent buffing the floors ranged from 64 to 97 minutes. School maintenance workers do not typically spray-buff floors for a full 8-hour work shift. According to school custodians at the five sites (Nos. 6A, 10A, 11A, 13B, and 16B) that showed mea-

TABLE IV. Overall Distribution of Asbestos Structures Measured by TEM Before and During Spray-Buffing of Resilient Floor Tile (Percentages)

	Type of Asbestos		Structure Morphology			
Sampling Period	**Chrysotile**	**Amphibole**	**Fibers**	**Bundles**	**Clusters**	**Matrices**
Before buffing	99.8	0.2	9.3	2.1	4.2	84.4
During buffing	99.7	0.3	18.8	1.6	2.5	77.1

sured levels above 0.1 f/cm^3, the average time spent buffing floors on a typical day ranges from 1.5 to 2.5 hours. Assuming that a custodian spends no more than 2.5 hours per day spray-buffing the floor and has no additional exposure to airborne asbestos for the remainder of the work shift, the maximum estimated 8-hour TWA concentration (0.093 f/cm^3, 8-hour TWA) would be less than the current OSHA action level of 0.1 f/cm^3. However, in actuality, the airborne asbestos concentrations after spray-buffing may decay very slowly and consequently custodians could have exposures greater than the OSHA action level.

Morphology and Size Distributions of Asbestos Structures

The TEM analysis of the 163 samples collected before and during spray-buffing yielded a total of 4598 asbestos structures, of which more than 99 percent where chrysotile and less than 1 percent were amphibole. This proportion of chrysotile and amphibole existed both before and during spray-buffing. The asbestos in nearly all floor tiles is chrysotile. Table IV summarizes the overall structure morphology distribution separately for each sampling period (i.e., before and during spray-buffing). Overall, the asbestos structures were primarily matrices (approximately 80 percent) and to a lesser extent, fibers, clusters, and bundles.

The structure morphology for asbestos structures observed before low-speed buffing was comparable to that observed during low-speed buffing. That is, similar percentages of fibers, bundles, clusters, and matrices were observed both before and during low-speed buffing. For example, the percentage of airborne asbestos fibers observed before and during low-speed buffing represented 8.9 percent and 12.3 percent of the total asbestos structures observed. Similarly, the percentage of asbestos matrices observed before and during low-speed buffing represented 84.8 percent and 84.4 percent of the total structures observed. The structure morphologies for asbestos structures observed during high-speed buffing, however, were distinctly different. The morphologies for asbestos structures observed during high-speed buffing showed that the percentage of asbestos fibers observed during high-speed buffing (25.5%) was approximately 2.5 times greater than the percentage of fibers observed before buffing (10.2%). In contrast, the percentage of asbestos matrices were greater before high-speed buffing (83.4%) than during buffing (69.6%). One possible explanation for a decrease in the number of asbestos matrices during buffing is that the high speed buffing pulverizes any asbestos-containing particles lying on the surface of the floor and/or any particles contained in the wax layer on the floor tile. This could also explain the increase in the percentage of asbestos fibers during high speed buffing. Another possible explanation for the increase in the percentage of asbestos fibers during high-speed buffing could be the abrasion of surficial fibers from the floor tile.

Overall, there did not appear to be any significant difference in the cumulative size distributions of asbestos structures before and during spray-buffing. In addition, less than 1 percent of the asbestos fibers measured before and during spray-buffing were greater than 5 μm in length. Although comparable structure size distributions were observed before and during low-speed buffing, a larger percentage of the structures observed during high-speed buffing (49.9%) were less than 1 μm compared to structures observed before high-speed buffing (34%). The increased number of structures less than 1 μm in length could be due to 1) the pulverization of asbestos structures on the floor surface and/or asbestos structures contained in the wax layer and/or 2) the abrasion of surficial fibers from the floor tile.

Conclusions

This study demonstrates that routine spray-buffing of a bestos-containing resilient floor tile can be a source of a bestos-containing particles in the building air. A statis cally significant increase in airborne asbestos concentr tions during spray-buffing was measured at seven of the schools studied.

Machine speed affects the level of airborne asbest concentrations generated during spray-buffing. On ave age, the airborne asbestos concentrations were appro mately five times higher during than before spray-buffi with the high-speed machines, whereas spray-buffing with the low-speed machines showed a twofold increase during buffing than before.

Machine speed also appears to have a significant effect on the morphology of the airborne asbestos structures generated during spray-buffing. The percentage of asbestos fibers observed during high-speed buffing was approximately 2.5 times greater than that before buffing; whereas, the percentage of asbestos fibers observed during low-speed buffing was approximately 1.3 times greater. The percentage of asbestos matrices measured during high-speed buffing was approximately 1.2 times lower than before buffing; whereas the percentage of asbestos matrices measured during low-speed buffing was essentially unchanged (i.e., less than 0.4% lower).

The U.S. EPA's Risk Reduction Engineering Laboratory is presently conducting a controlled field research study to evaluate the extent of asbestos release during application of low-speed spray-buffing (i.e., 300 rpm) and ultra-high speed buffing (i.e., 2000 rpm) on three levels of the floor care (poor, intermediate, and good). The results of this study will define the condition of the floor which minimizes or prevents the release of asbestos structures during spray-buffing.

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References

1. American Standard Testing Materials: Standard Definitions of Terms Relating to Polishes and Related Materials. Standard D2825-69. Committee D-21 and Subcommittee D21.91. Washington, DC (1984).
2. U.S. Environmental Protection Agency: Evaluation of Asbestos Fiber Release During Maintenance of Asbestos-Containing Floor tile. Final Report. Chemical Management Division, Office of Pollution Prevention and Toxics, Washington, DC (1992).
3. U.S. Environmental Protection Agency: Airborne Asbestos Concentrations During Buffing of Resilient Floor Tile in New Jersey Schools. Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio (1993).

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