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Project Summary

Assessment of Asbestos Removal Carried Out Using EPA Purple Book Guidance

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An evaluation was made of airborne asbestos data collected before, during, and after removal of spray-applied asbestos-containing fireproofing at three university buildings. Each abatement project was conducted in accordance with the work practices and procedures recommended by the U.S. Environmental Protection Agency in "Guidance for Controlling Asbestos-Containing Materials in Buildings," (the Purple Book).

Containment barriers should be designed so they effectively prevent a significant increase in airborne concentrations outside the work area during and after abatement. An increase in asbestos concentration outside the work area could allow an abatement site to be cleared when the level inside the containment is similarly elevated. This holds true whether phase contrast microscopy or transmission electron microscopy is used for the clearance.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Office of Pesticides and Toxic Substances of the U.S. Environmental Protection Agency (EPA) provides guidance and information on the identification of asbestos-containing materials in buildings and on the abatement actions for potential asbestos hazards.

The EPA guidance in effect at the time of this study, entitled "Guidance for Controlling Asbestos-Containing Materials in Buildings," EPA 560/5-85-024 (June 1985), known as the "Purple Book," contains recommendations for work practices and procedures to be used in performing asbestos-abatement projects. The recommendations include 1) constructing airtight plastic containment barriers around the work area, 2) using negative-pressure air filtration systems, 3) wetting all asbestos-containing material (ACM) prior to its removal, 4) containerizing of ACM and asbestos-contaminated debris while it is wet, 5) conducting rigorous postabatement cleanup with wet cleaning and high-efficiency particulate air (HEPA) filtered vacuuming techniques, and 6) performing visual inspections and air monitoring to determine asbestos-abatement completion and work area decontamination.

The EPA guidance document recommends that air monitoring for post-abatement clearance be conducted after the work area has passed a thorough visual inspection. According to the EPA "Purple Book" guidance, two methods for measuring airborne asbestos can be used: transmission electron microscopy (TEM) and phase contrast microscopy (PCM). If TEM is used, at least five samples from inside and five samples from outside each homogeneous work area should be collected. The average of the work-area concentrations should be statistically (t-test) no larger than the average of measured concentrations outside the work area. If PCM is used, at least five samples from inside each homogeneous work area should be collected, and none of the concentrations should be higher than the reliable limit of quantitation (approximately 0.01 f/cm^3). Although the Purple Book recommends TEM as the method of choice based on its sensitivity to smaller fibers and specificity for asbestos, the decision to select an air sampling protocol for determining successful abatement completion is left to the abatement project manager. Thus, the determination of work-area cleanliness

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depends on which method is chosen for measuring asbestos fibers.

Although the Purple Book contains the latest EPA-recommended guidance for work practices and procedures to be used in performing asbestos-abatement projects, it did not represent the latest EPA guidance for clearance testing of an abatement site at the time the study report was prepared. This guidance is presented in the final rule (October 30, 1987; 52 FR 41826) for the Asbestos Hazard Emergency Response Act (AHERA) of 1986. The final rule establishes TEM as the preferred analytical method to be used for analysis of samples taken for clearance air monitoring and also specifies a procedure for determining when an asbestos site is sufficiently clean for the critical containment barriers to be removed. The procedure requires the collection of five samples from inside and five samples from outside the abatement work area, but not necessarily outside of the building. The average of the concentrations inside the work area must be statistically (Z-test) no larger than the average of measured concentrations outside the work area.

Study Objectives

The following were the primary objectives of the study:

- To determine the effectiveness of containment barriers in preventing the release of asbestos fibers outside of the work area.
- To determine the effectiveness of final cleanup procedures.
- To evaluate the TEM clearance criteria for both the t-test and, to the extent that the data allow, the Z-test.
- To determine if an abated site meets both TEM and PCM clearance criteria and to evaluate whether PCM provides false positives for clearance decisions.
- To determine if 0.8-µm pore-size mixed cellulose ester and 0.4-µm pore-size polycarbonate membrane filters produce equivalent estimates of airborne asbestos concentrations.

Project Description

Site Selection

The three study sites, which were all school buildings, were chosen based on the following selection criteria:

1. No significant abatement of ACM had occurred inside the building site within the last 12 mo.
2. Each abatement site was in a different geographical location or building.
3. The abatement project involved the removal of spray-applied asbestos-containing fireproofing from structural members and decking.
4. The abatement project was governed by written specifications that comply with the minimum requirements in the latest EPA guidance document (the Purple Book).
5. The building owner and abatement contractor agreed to cooperate with the EPA and to provide access to selected areas of the building.

Abatement Programs

The abatement contractors prepared the work areas, removed the asbestos-containing fireproofing, and conducted decontamination activities in accordance with the latest EPA guidance (the Purple Book). The abatement activities were performed in three distinct stages: preparation, removal, and decontamination. Work areas were prepared by removing all movable objects; turning off the ventilation and electrical systems; sealing off all air ducts and openings; covering the floors, walls, and immovable objects with plastic sheeting; installing HEPA-filtered, negative-pressure air filtration systems; and constructing two entrance and egress contamination-control facilities—one with showers and change rooms for personnel and the other for waste-material handling. Suspended ceilings and carpeting were either removed and disposed of as contaminated waste or cleaned and disposed of by conventional means.

Workers wearing full protective clothing and approved respiratory protection removed the fireproofing by first wetting the material with an amended water solution and then scraping it off. The asbestos-containing debris was placed in double 6-mil polyethylene bags and disposed of at an approved sanitary landfill. All substrate surfaces from which asbestos was removed were wire-brushed and wet-wiped repeatedly to remove as much of the fireproofing material as possible. All stripped or potentially contaminated surfaces were sprayed with an asbestos sealant to bond any residual fibers to the substrate. During decontamination of the work area, all loose debris was removed, as was the plastic sheeting from the walls and floors. Decontamination also involved two complete final cleanups entailing wet-wiping or mopping of the walls and floors. At Site 1, an 8-h period elapsed between the final cleanings; at Site 2, a 24-h period elapsed between cleanings. The work areas were then visually inspected to assure the absence of debris and visible dust on surfaces. When the work area passed a thorough visual inspection and air monitoring showed that the total fiber concentrations were less than 0.01 f/cm³ (by phase contrast microscopy), all remaining critical containment barriers (on windows, doors, and vents) were removed, and the area was considered acceptable for reoccupancy.

Sampling Strategy

At each of the three abatement sites, area air samples were collected before, during, and after removal of the spray-applied asbestos-containing fireproofing. Samples were collected inside the work area (i.e., the abatement area); outside the work area (i.e., the perimeter area outside the abatement area); and from the ambient air (i.e., outside of the building). Side-by-side samples were collected at each location for separate PCM and TEM analysis.

The preabatement air samples were collected inside and outside the work area before the containment barriers were constructed. The sampling was conducted under static conditions (i.e., activity in the area was minimal and the heating, ventilating, and air-conditioning system was not in operation).

During the removal phase of the abatement, air samples were collected outside the work area at scheduled intervals and under static sampling conditions.

The postabatement air samples outside the work area also were collected under static sampling conditions. The postabatement air samples inside the work area were collected under aggressive sampling conditions. The aggressive sampling conditions were created by sweeping all horizontal and vertical surfaces with a hand-held, electric-powered, leaf blower and then using floor fans to generate continuous air turbulence throughout sampling period.

Sampling Methods

Two side-by-side area air samples were collected at each sampling location inside and outside the work area and outdoors. Each pair of samples consisted of a 25-mm, 0.4µm pore size, Nuclepore* polycarbonate filter and a 25-mm, 0.8-µm pore size, Millipore mixed cellulose ester filter. Each 25-mm filter was mounted on a 5-µm pore size, mixed cellulose ester, backup diffusing filter and cellulose support pad and was contained in a three-piece cassette with a 50-mm conductive cowl and face cap. The filter cassettes were positioned 4 to 5 ft above the floor and were arranged in a horizontal line by clipping them to a

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

sturdy stand. The filter cassettes were placed approximately 5 cm apart and were oriented in the same direction with the filter face angled slightly downward. During sampling, the face cap was removed to expose the full face of the filter to the air stream.

The filter assembly was attached to an electric-powered vacuum pump. An inline calibrated precision rotameter was used to regulate the air-flow rate through the filter assembly at 8 to 12 L/min. The air samples were generally collected for a period of approximately 6 to 9 h to achieve a minimum air volume of 3,000 L for each sample; however, a limited number of samples were collected for periods extending up to 17 h, which yielded air volumes of approximately 11,000 L.

Methods of Analysis

Phase-Contrast Microscopy

The mixed cellulose ester membrane filters were analyzed by PCM, and the polycarbonate membrane filters were analyzed by TEM. The PCM and TEM analytical protocols are presented in the Quality Assurance Project Plan (QAPP) prepared for this research study.

The mixed cellulose ester filters were prepared and analyzed for total fibers by PCM in accordance with National Institute of Safety and Health Method 7400.

Transmission Electron Microscopy (TEM)

The polycarbonate membrane filters were analyzed by TEM. The filters were prepared and analyzed for asbestos fibers by TEM in accordance with the Yamate Revised Method. A TEM Level II analysis was performed on all polycarbonate samples collected in this study.

Quality Assurance

The QAPP contains the complete details of the quality assurance procedures followed during this research project.

Specific quality assurance procedures used to ensure the accuracy and precision of the TEM analysis of air samples included the use of lot blanks, field blanks, and replicate TEM analyses.

Lot blanks are unused filters submitted for prescreening analysis for background contamination before the start of field work to determine the integrity of the entire lot of filters purchased for EPA field studies. Analysis of 100 lot blanks showed an average background contamination of 1.8 asbestos structures per 10 grid openings. The lot of filters was subsequently considered "acceptable" for use because the average asbestos structure count did not exceed 3 structures per 10 grid openings.

Field blanks are filters taken into the field and handled in the same manner as exposed air samples to check for contamination that might not be a result of air sampling. A total of 27 field blanks were collected at Sites 1, 2, and 3. Because the average asbestos structure count did not exceed 3 asbestos structures per 10 grid openings at any site, background contamination was not considered a problem.

Replicate sample analysis provides a means of quantifying analytical variability introduced by the filter preparation procedure and refers to the analysis of different filter preparations from the same sample. The replicate analyses showed no significant tendency toward higher or lower structure counts.

Statistical Analysis Methods

Nonparametric statistical methods were selected to analyze the data collected during this study. Nonparametric procedures analyze the relative ranks of the data rather than the actual data values, and they do not require any assumptions regarding the form of the underlying statistical distribution of the data.

The Kruskal-Wallis one-way analysis procedure was used to examine the differences between airborne asbestos concentrations in the perimeter area before, during, and after abatement. The Wilcoxon rank sum test was used to make all other comparisons.

The TEM clearance comparison was made with the Student's t-test as recommended in the Purple Book, and to the extent the data allowed, with the Z-test required in the AHERA final rule. Because all three sites used negative-pressure air filtration systems during abatement and the makeup or "background" air came from other parts of the building rather than directly from outdoors, the postabatement samples inside the work area were compared with the postabatement samples outside the work area but within the building.

Results

Average airborne asbestos concentrations and respective sample sizes are presented in Table 1. The results are presented for Sites 1, 2, and 3 by abatement phase (before, during, and after); location of sample (inside the work area, outside the work area, and ambient); and microscopy technique (TEM and PCM). Figure 1 presents average airborne asbestos concentrations graphically for Sites 1, 2, and 3 according to abatement phase and sample location. The study report includes a detailed presentation and discussion of the results for each site, including plots of structure lengths and diameters determined by TEM analysis.

Conclusions

The following principal conclusions from this study are presented for each study objective.

Comparison of Concentrations Outside the Work Area

Asbestos concentrations measured outside the work area before, during, and after abatement at Sites 1 and 3 did not vary significantly. This indicates that the containment barriers at these two sites were effective in preventing the release of asbestos fibers outside the work area. At Site 2, however, the asbestos concentrations measured after abatement were significantly higher than those measured before and during abatement. The average asbestos concentration after abatement was approximately 80 times higher than the average concentration before abatement. These elevated asbestos concentrations suggest that 1) the containment barrier was not effective at this site; 2) work practices recommended in the Purple Book were not followed; or 3) asbestos-containing material outside the abatement containment was disturbed, which resulted in elevated asbestos concentrations in that area.

Comparison of Work Area Concentrations Before and After Abatement

At Site 1, asbestos concentrations did not increase significantly after abatement. At Sites 2 and 3, however, asbestos concentrations did increase significantly after abatement.

Final cleanup procedures can effectively control postabatement airborne asbestos concentrations inside the work area. The higher postabatement concentrations may be attributable to improper or inadequate implementation of final cleanup procedures, or they may be due to sampling conditions (i.e., static conditions in the preabatement phase versus aggressive conditions in the postabatement phase, or both).

TEM Clearance Comparisons

Sites 1, 2, and 3 passed the TEM clearance criteria for both the t-test recommended in the Purple Book and Z-test specified in the final rule under AHERA. At Site 2, the increase in the postabatement asbestos concentration outside the work

Table 1. *Average Airborne Asbestos Concentrations Before, During, and After Abatement at Sites 1, 2, and 3*

Location	Site 1 TEM	Site 1 PCM	Site 2 TEM	Site 2 PCM	Site 3 TEM	Site 3 PCM
	Average Airborne Asbestos Concentration (s/cm³)/Sample Size					
	Preabatement phase					
Ambient	0.0041/3	0.0007/3	0.0011/5	0.0012/5	0.0000/3	0.0020/3
Perimeter	0.0052/12	0.0003/12	0.0030/5	0.0014/5	0.0008/3	0.0040/3
Work area	0.0091/10	0.0000/10	0.0367/5	0.0012/5	0.0001/8	0.0020/8
	During-abatement phase					
Ambient	0.0034/4	0.0008/4	0.0005/5	0.0010/5	—[a]	—
Perimeter	0.0089/31	0.0023/31	0.0304/31	0.0015/31	0.0129/49	0.0106/61
Work area	—	—	—	—	—	—
	Postabatement phase					
Ambient	0.0067/4	0.0002/5	—	—	0.0000/3	0.0107/3
Perimeter	0.0057/5	0.0022/5	0.2410/7	0.0027/7	0.0028/2	0.0074/5
Work area	0.0056/5	0.0015/5	0.3082/5	0.0024/5	0.0023/7	0.0080/7

[a] Dashes indicate that no samples were collected.

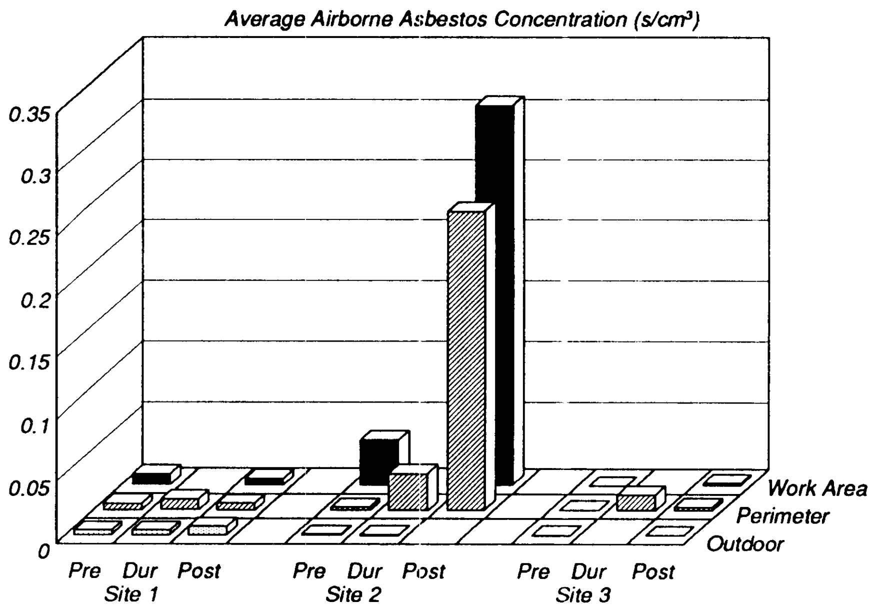

Figure 1. Mean airborne asbestos concentrations before, during, and after abatement for samples analyzed by TEM at sites 1, 2, and 3.

area, as noted in the preceding discussion, enabled the site to pass both clearance tests. Conversely, a comparison of the postabatement concentrations inside the work area with ambient concentrations resulted in the site failing both clearance tests. This single incident points up a serious limitation in the comparison of postabatement asbestos concentrations inside the work area with those outside the work area.

Both the Purple Book and AHERA final rule clearance strategies could allow an abatement site to be cleared despite the fact that the airborne asbestos concentration outside the work area is significantly higher than preabatement building concentrations.

Comparison of TEM and PCM Clearance Test Results

Sites 1, 2, and 3 passed the TEM clearance criteria based on both the t-test (Purple Book) and the Z-test (AHERA final rule). Sites 1 and 2 also passed the PCM clearance criterion (0.01 f/cm³); however, Site 3 failed. Thus, this study identified a false positive PCM clearance situation where a site failed PCM and passed TEM.

The differences in conclusions reached by the two protocols are probably due to the limited ability of PCM to distinguish asbestos from nonasbestos materials. Airborne fiber concentrations estimated by PCM reflect total fiber concentrations, not just asbestos fiber concentrations; therefore, they may lead to erroneous conclusions regarding abatement clearance.

Comparison of Concentrations Measured on Mixed Cellulose Ester and Polycarbonate Filters

The TEM analysis of 69 paired 0.8-µm pore size mixed cellulose ester and 0.4-µm pore size polycarbonate membrane filters revealed a statistically significant difference in asbestos concentrations on the two filter types. This comparison was made because the guidance in the Purple Book allowed for the choice of either type of filter. Asbestos concentrations on 0.4-µm pore size polycarbonate filters were significantly higher than those on 0.8-µm pore size mixed cellulose ester filters. The two types of filters do not produce equivalent estimates of airborne asbestos concentrations. The difference in asbestos concentrations may be due to the differences in the pore sizes or in the chemical composition of the two types of filters.

Recommendations

Because the elevated levels outside the containment area at Site 2 would have allowed a contaminated site to pass under the AHERA sampling strategy, monitoring of the contamination level outside the work area during abatement or after abatement should be strongly considered as a prerequisite to using this area as a clearance reference point. If additional monitoring is not considered reasonable, the guidance should be revised to emphasize the importance of the location of the "outside" samples.

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The complete report, entitled "Assessment of Asbestos Removal Carried Out Using EPA Purple Book Guidance," (Order No. PB91-148338/AS; Cost: $17.00, subject to change) will be available only from:
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