AN EVALUATION OF ASBESTOS MANAGEMENT PROGRAMS IN 17 NEW JERSEY SCHOOLS
A Case Studies Report

by

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and

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DISCLAIMER

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, to measure the impacts, and to search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible, engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report provides information on airborne asbestos concentrations measured four years after asbestos abatement at 17 schools in New Jersey. Reviews of each school's Asbestos Management Plan, air monitoring, and thorough visual inspections were conducted to evaluate the asbestos management programs at these schools. Case histories of each school are provided, which summarize data collected during 1988, 1990, 1991, and 1992.

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ABSTRACT

From 1988 through 1992, the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory (EPA-RREL) and the New Jersey Department of Health's Environmental Health Service (NJDOH-EHS) conducted studies in 17 schools in New Jersey to evaluate their asbestos management programs.

Findings of a study conducted in 1988 to document Asbestos Hazard Emergency Response Act (AHERA) final clearance concentrations of asbestos at these 17 schools prompted a followup study in 1990 to determine the airborne asbestos concentrations 2 years after the abatement efforts. Although the 1990 study provided data regarding airborne asbestos levels during simulated occupancy conditions 2 years after abatement, whether these data were representative of levels during actual occupancy was uncertain.

Another followup study conducted in May 1991 to determine the airborne asbestos concentrations during actual occupied conditions showed airborne asbestos levels to be above the AHERA initial screening criterion of 70 s/mm^2 at eight of the sites. Reentrainment of residual asbestos-containing debris from the 1988 abatement or from operations and maintenance activities may have contributed to these elevated airborne asbestos concentrations.

In 1992, EPA/NJDOH conducted a final study at the 17 schools to measure airborne asbestos levels during actual occupied conditions 4 years after abatement. This report presents the results of the 1992 study and integrates the results of the three previous studies to evaluate the asbestos management programs in these schools. It also presents case histories of each study site that summarize the findings of the 1988, 1990, 1991, and 1992 studies.

Environmental Quality Management, Inc., submitted this document to the U.S. Environmental Protection Agency's Office of Research and Development, Risk Reduction Engineering Laboratory, in partial fulfillment of Contract No. 68-D2-0058. The report covers the period of June 1988 through September 1992, and work was completed as of September 30, 1993.

CONTENTS

FIGURES

TABLES

(continued)

TABLES (continued)

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) recommends a pro-active, in-place management program whenever asbestos-containing material is present in buildings.[1] Asbestos removal is required only when necessary to prevent significant public exposure to airborne asbestos structures during building demolition or renovation activities.[2] The ultimate goal of every asbestos abatement project is to eliminate, or reduce to the extent possible, the actual or potential hazard airborne asbestos structures may present to building occupants. If all safeguards are not properly applied,[3] asbestos removals may actually elevate airborne levels of asbestos structures in a building.[1,4]

The Risk Reduction Engineering Laboratory (RREL) of EPA and the Environmental Health Service (EHS) of the New Jersey Department of Health (NJDOH) conducted a series of studies to measure residual airborne asbestos levels immediately after and 2 to 4 years after abatement in 17 New Jersey Schools.[5,6,7,8] The primary purpose of these studies was to evaluate the asbestos management programs in these schools.

Background

In 1988, EPA-RREL and NJDOH-EHS conducted a study to document Asbestos Hazard Emergency Response Act (AHERA) air-sampling practices during final clearance and to measure final clearance concentrations of airborne asbestos at 20 projects involving removal of asbestos-containing material (ACM) in 17 New Jersey schools.[5,6] This study identified significant discrepancies between the airborne asbestos concentrations measured by the Asbestos Safety Control Monitor (ASCM) firms employed by the school and those measured independently by EPA/NJDOH. In general, the EPA/NJDOH samples showed that significant levels of airborne asbestos remained in 10 of the schools that passed the AHERA clearance tests based on the ASCM data. These 10 schools would have failed the AHERA initial screening criterion of 70 asbestos structures per square millimeter (s/mm^2), and 7 of the schools would also have failed the AHERA Z-test.[9]

In 1990, EPA/NJDOH conducted a study at the same 17 schools to measure airborne asbestos concentrations 2 years after the abatements in 1988.[7] The samples were collected in August when the schools were unoccupied; however, occupied conditions were simulated by using a modified aggressive sampling protocol. Fifteen of the schools showed airborne asbestos levels significantly less than those measured in 1988; however, two schools showed significantly higher concentrations in 1990 than in 1988. The reduction in airborne asbestos levels could be attributed to the monitoring being conducted after the schools completed their summer janitorial cleaning. Although the 1990 study provided valuable data regarding the residual levels of asbestos 2 years after abatement, the extent to which these data represented conditions of actual occupancy remained uncertain.

In 1991, EPA/NJDOH measured airborne asbestos concentrations at the 17 schools 3 years after the 1988 abatement.[8] The samples were collected during actual occupied conditions (i.e., during normal school hours). At the eight schools showing average airborne asbestos concentrations above the AHERA initial screening criterion of 70 s/mm^2, the NJDOH-EHS required response actions to be taken to lower the airborne asbestos levels below the criterion of 0.02 asbestos structures per cubic centimeter (s/cm^3) of air sampled.

In 1992, EPA/NJDOH conducted a final study at the 17 schools to measure airborne asbestos levels under actual occupied conditions 4 years after abatement.

This report presents the results of the 1992 study and integrates the results from the previous studies to evaluate the asbestos management programs at these schools. Also presented are case histories of each study site, which summarize the findings of the 1988, 1990, 1991, and 1992 studies.

Objectives

The objectives of the study were as follows:

- To determine the airborne asbestos levels measured during occupied conditions in 17 schools that underwent abatement in 1988.
- To evaluate the airborne asbestos levels measured in the 17 schools over the 4-year period (1988, 1990, 1991, and 1992).
- To determine the accuracy of each school's Asbestos Management Plan for the areas monitored.
- To determine the possible sources of airborne asbestos in schools with elevated levels.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following are the principal conclusions reached during this study:

1) Overall, when all of the 20 sites were considered collectively, there was no apparent trend toward progressively increasing airborne asbestos concentrations 2 to 4 years after the 1988 abatements. There were a number of sites, however, where elevated airborne asbestos concentrations were measured immediately after and 2 to 4 years after the 1988 abatements.

   ° In 1988, 1991, and 1992, the average airborne asbestos concentrations measured by transmission electron microscopy in the 1988 abatement and/or perimeter areas exceeded the New Jersey Department of Health response action criterion of 0.02 s/cm^3 at 10, 8, and 6 of the 20 sites, respectively.

   ° Overall, in 1988, 1990, and 1991, postabatement airborne asbestos concentrations measured in the 1988 abatement and/or perimeter areas were statistically significantly greater than those measured outdoors. Although individually the airborne asbestos concentrations in the 1988 abatement and perimeter areas were not significantly different from those measured outdoors in 1992, when these concentrations were combined, they were significantly greater than those measured outdoors.

   ° Overall, approximately 5 percent of the asbestos structures measured in 1988, 1990, 1991, and 1992 at these 17 schools were greater than 5 µm in length.

   ° Overall at nine schools, airborne asbestos concentrations in the perimeter areas after the 1988 abatement were statistically significantly higher than those measured before the abatement.

   ° Overall, differences between airborne asbestos concentrations measured at these 17 schools in 1988, 1990, 1991, and 1992 were not statistically significant in the perimeter areas. Airborne asbestos concentrations measured in the abatement area in 1988 were statistically significantly greater than those measured in 1990 and 1992.

2) Response actions conducted by the schools in 1991 and 1992 demonstrated that elevated airborne asbestos levels (i.e., ≥ 0.02 s/cm^3) can be reduced to acceptable levels. Response actions reduced the levels of airborne asbestos to below 0.02 s/cm^3; however, five of the eight schools requiring a response action in 1991, again required a response action in 1992.

3) Asbestos-containing debris from the 1988 abatement and from postabatement operations and maintenance (O&M) activities may have contributed to the elevated airborne asbestos levels (>0.02 s/cm^3) present in 1991 and/or 1992 at nine sites.

  - The location of the asbestos-containing debris found at six sites indicates that the residual debris from the 1988 abatement may have contributed to the elevated airborne asbestos levels at these sites.

  - O&M activities that disturbed asbestos-containing materials (including thermal system insulation and plaster, and resilient floor tile) may have contributed to elevated airborne asbestos levels at three sites.

4) Errors in the Asbestos Management Plans or their implementation were documented and at several schools may have resulted in the accidental disturbance of asbestos-containing materials (ACM).

  - At 13 of the 17 schools, the Management Plan contained at least one error relating to material identification or material location.

  - At two schools, O&M activities that disturbed ACM (not identified in the Management Plan) may have contributed to the elevated airborne asbestos levels.

  - At one school, O&M activities that disturbed ACM (identified in the Management Plan) may have contributed to the elevated airborne asbestos levels.

5) A standardized visual inspection is an effective tool to determine the presence of residual asbestos-containing debris that may potentially become reentrained.

6) When the AHERA Z-test is used to clear an abatement project, it is generally more appropriate to utilize the outdoor samples as the reference point than the perimeter samples collected inside the building.

- At nine schools, airborne asbestos levels in the perimeter areas after the 1988 abatement were significantly higher than those measured before the abatement. (Results of preabatement samples collected in the perimeter areas and outdoors did not differ significantly).

- The Z-test, utilizing outdoor samples as the "outside values", matched the results of the AHERA initial screening criterion at 18 of the 20 sites.

7) Consultants who conducted the school's clearance air monitoring in 1988 often did not completely understand and follow the AHERA sampling and analytical requirements and recommendations. Practices observed during clearance monitoring included, inadequate drying of the abatement area prior to sampling, use of improper sampling medium and flow rates, inadequate aggressive air sweeping of surfaces, and insufficient use of circulating fans to maintain air movement during sampling.

8) In 1988, AHERA clearance concentration discrepancies existed between results of sample analyses reported by the school's consultant and those reported independently by EPA/NJDOH. Twelve of the 20 abatement sites would have failed the AHERA initial screening test had the EPA/NJDOH sample analyses been used. Ten of these sites would have subsequently failed the AHERA Z-test by using outdoor levels in the comparison.

9) Sampling factors typically encountered during the summer in schools (e.g., unoccupied conditions, reduced level of activity, major cleaning efforts, inoperative heating, ventilation, and air-conditioning system) can yield results that may not be representative of occupied conditions during the school year.

    - Sampling results during unoccupied conditions in 1990 showed no average airborne asbestos levels above 0.02 s/cm^3. Eight sites showed average levels of airborne asbestos above 0.02 s/cm^3 during occupied conditions in 1991, however. Similarly, six sites showed average levels of airborne asbestos above 0.02 s/cm^3 during occupied conditions in 1992.

    - Average airborne asbestos concentrations measured during unoccupied conditions in 1990 in the 1988 abatement and perimeter areas and outdoors were numerically lower than the other two years of monitoring.

Recommendations

1) A study should be conducted to evaluate the long-term effectiveness of asbestos response actions (e.g., cleaning, encapsulation, enclosure, repair) in schools. This information would assist EPA in evaluating the need for issuance of guidance on asbestos response actions.

2) Although not specifically required by AHERA, schools should evaluate the effectiveness of their asbestos O&M Program and periodic surveillance. Areas of the building that have undergone an asbestos-removal or O&M activity (involving ACM) should be thoroughly reinspected for the presence of residual asbestos-containing debris. If asbestos-containing debris is observed, a thorough cleaning and follow-up air monitoring should be conducted.

3) Each school should maintain and update its Management Plan to keep it current with ongoing O&M, periodic surveillance, inspection, reinspection, response actions, and post-response action activities. The school should ensure that workers who may disturb ACM are aware of changes in the Management Plan.

4) EPA cooperatively with State Agencies need to provide further outreach and education to all responsible parties such as Local Education Agencies, AHERA designated persons, and consultants, to enhance their understanding of the intent and requirements of AHERA. Thorough regulatory oversight is necessary to ensure compliance within the requirements of AHERA.

5) Outdoor air samples should be used as the "outside values" in the AHERA Z-test because they are less likely to be affected by work practices that may contaminate other areas inside the building.

6) A standardized visual inspection technique (e.g., ASTM Standard E1368) should be included in the AHERA final clearance procedure. Furthermore, this type of standardized visual inspection procedure (or a variation thereof) should be incorporated into the three-year AHERA Asbestos Management Plan reinspections (40 CFR 763.85).

7) A comprehensive guidance document should be developed that addresses the procedures and protocols for conducting a standardized visual inspection and AHERA clearance air sampling. This document would supplement existing EPA guidance (Guidelines for Conducting the AHERA TEM Clearance Test to Determine Completion of an Asbestos Abatement Project--EPA 560/5-89-001) which emphasizes interpretation of AHERA clearance results.

SECTION 3

STUDY DESIGN AND METHODS

This study was conducted at the same 17 schools involved in the 1988 EPA/NJDOH study, that documented AHERA air monitoring practices and final clearance concentrations of airborne asbestos,[5,6] in the 1990 EPA/NJDOH study that measured airborne asbestos concentrations 2 years after abatement,[7] and in the 1991 EPA/NJDOH study that measured airborne asbestos concentrations 3 years after abatement.[8]

The 17 schools involved 20 abatement sites. Although the original selection of the 20 abatement sites in 1988 was based largely on availability, each site also met specific criteria. The criteria included 1) building used as a school, 2) removal of various types of ACM (e.g., spray-applied fireproofing), and 3) the abatement project was cleared in accordance with AHERA clearance procedures. Access to each school was coordinated directly by NJDOH-EHS. Area airborne asbestos concentrations were measured at each site in the same three areas as in the previous studies: 1) the previously abated area (hereafter referred to as the 1988 abatement area), 2) the perimeter area (outside the 1988 abatement area but inside the building), and 3) outdoors. The actual abatement and perimeter areas could not be separated because the containment barriers present during the 1988 abatement had been removed. It was also recognized that, in the interim since 1988, other sources (e.g., routine maintenance of asbestos-containing resilient floor tile or other O&M activities involving asbestos-containing building materials) may have contributed to the current concentrations of airborne asbestos.

One objective of the study was to measure airborne asbestos concentrations during occupied conditions at the 17 schools that underwent abatements in 1988. Although these 17 schools did not represent a statistical random sample, there was no identifiable biases in this sample of schools or in the abatement methods used. The only likely difference in the schools was their current status with regard to the presence of ACM. Hence, the data from each of the 20 sites were combined for statistical analysis to reach conclusions about the 17 schools.

Air Sampling Strategy

The air sampling strategy for this study consisted of monitoring during periods of occupancy at all 17 schools representing the 20 sites. Response actions were conducted at sites with average airborne asbestos concentrations above 0.02 s/cm^3.

The 0.02 s/cm^3 criterion was derived from the AHERA initial screening criterion of 70 s/mm^2 (40 CFR 763) and was used by NJDOH-EHS as a level that, if exceeded, required the school to initiate a response action to reduce the airborne asbestos concentration to below 0.02 s/cm^3. A modified aggressive air sampling protocol was used to conduct followup sampling to determine the completion of the response actions. Table 1 summarizes the air sampling strategy for this study and those for the three preceding studies in 1988,[5,6] 1990,[7] and 1991.[8]

TABLE 1. SUMMARY OF AIR SAMPLING STRATEGIES

Period of study	No. of sites	Conditions of sampling	Monitoring criteria
June-July 1988	11	Passive[a]	Determine preabatement levels
July-Sept. 1988	16	Abatement conditions	Determine pre-final cleanup levels
July-Sept. 1988	20	Aggressive[b]/ passive	AHERA final clearance
July-Aug. 1990	20	Modified aggressive[c]	Two-year followup
May 1991	20	Occupied	Three-year followup
August 1991	10	Modified aggressive	Confirm if levels exceeded 0.02 s/cm^3
August 1991	4	Modified aggressive	Verify completion of followup response action
Sept. 1991	1	Modified aggressive	Verify completion of followup response action
May 1992	20	Occupied	Four year followup
July-Aug. 1992	6	Modified aggressive	Verify completion of response action

[a] Minimal occupant activity in the area.

[b] Aggressive sampling protocol in accordance with AHERA - 40 CFR 763.

[c] Sampling protocol to simulate normal occupant activity, including air sweeping of floors with exhaust of 1-hp leaf blower and positioning of one stationary fan per 10,000 ft^3.

May 1992

At each site, five area air samples were collected in each of three areas: 1) the 1988 abatement area 2) the perimeter area (outside the 1988 abatement area but inside the building), and 3) outdoors. Table 2 shows the number of air samples collected at each site. The air samples were collected at approximately the same locations as those collected during the 1988, 1990, and 1991 studies. In addition to the area air samples, three quality assurance samples (one closed and two open field blanks) were collected at each school.

The samples were collected during periods of occupancy (i.e., during school hours, 8:00 am to 3:00 pm). Because certain sampling situations (e.g., inside a classroom) could not tolerate noise from an electrically powered sampling pump, the pumps were placed in special acoustical cases designed to attenuate the noise of the

TABLE 2. NUMBER OF AREA AIR SAMPLES COLLECTED AT EACH SITE DURING OCCUPIED CONDITIONS IN MAY 1992

Site	Number of samples and location		
	1988 Abatement area	Perimeter	Outdoors
A	5	5	5
B	5	5	5
C	5	5	5
D	5	5	5
E	5	5	5
F	5	5	5
G	5	5	5
H	5	5	5
I	5	5	5
J	5	5	5
K	5	5	5
L	5	5	5
M	5	5	(5)[a]
N	5	5	(5)[b]
O	5	5	5
P	5	5	5
Q	5	(5)[c]	(5)[c]
R	5	5	5
S	5	5	5
T	5	5	5
Total samples	100	95	85

[a] Same samples as collected at Site C (i.e., Site M was the second abatement project at this school).

[b] Same samples as collected at Site K (i.e., Site N was the second abatement project at this school).

[c] Same samples as collected at Site B (i.e., Site Q was the second abatement project at this school).

sampling pump to a sound pressure level of <40 dB (RE 20 N/m^2) at a distance of 3 ft. A noise level of 40 dB is rated as "quiet" for private offices and conference rooms.[10]

July-August 1992

Based on the May 1992 sampling, five schools representing six sites were required to conduct a response action in the 1988 abatement area and/or perimeter areas to reduce the risk of exposure to airborne asbestos in these school buildings. The response action taken at each of the schools primarily involved cleaning the areas to remove all visible dust and debris. Subsequent to the response actions, EPA/NJDOH collected additional area air samples in the affected areas to establish that they were below 0.02 s/cm^3. The number and locations of the samples were the same as those collected in May 1992.

Site Documentation

For each of the 17 schools monitored in May of 1991 and 1992, the NJDOH-EHS documented the history of the abatement activities between 1988 and 1992 and O&M activities on any remaining asbestos-containing material (ACM) in the 1988 abatement area and perimeter area. This information was obtained from abatement notices required under the New Jersey Administrative Codes (N.J.A.C. 8:60-7 and N.J.A.C. 12:120-7), from AHERA Asbestos Management Plans, and by the AHERA Designated Person and/or school officials who were interviewed.

NJDOH Inspections

In 1991, a certified AHERA building inspector from NJDOH-EHS conducted an inspection at each of these schools. The inspection included a review of the school's Asbestos Management Plan relating to the 1988 abatement areas and perimeter areas and a visual inspection of these areas. In July through August 1992, a followup visual inspection was conducted at four schools with elevated airborne asbestos levels (i.e., ≥0.02 s/cm^3) based on monitoring conducted in May 1992.

Management Plan Review

Prior to conducting the visual inspection, each school's Asbestos Management Plan was reviewed. The Asbestos Management Plan describes all activities planned and undertaken by a school to comply with AHERA (40 CFR 763), including building inspections to identify ACM, response actions, and O&M programs to minimize the risk of exposure to airborne asbestos in school buildings.

The review included 1) recording the material category (e.g., thermal system insulation), material type (e.g., pipe insulation), amount of material (e.g., linear feet) and condition of material (e.g., damaged) remaining in the 1988 abatement areas and perimeter areas; 2) recording response actions (e.g., removal, encapsulation, enclosure, repair, or O&M); and 3) recording renovations or asbestos abatements that occurred after the 1988 abatement. This information was then compared with that obtained during the visual inspection of the 1988 abatement and perimeter areas to determine the accuracy of the original AHERA inspection regarding the identification, assessment, and location of ACM in these areas.

Visual Inspections

The visual inspection was not intended to be a comprehensive assessment of the ACM in the school; rather, it was designed to focus on the areas monitored (i.e., 1988 abatement areas and perimeter areas) in an attempt to locate the possible sources of the airborne asbestos contamination measured in May of 1991 and 1992. This approach assumed that the elevated airborne asbestos levels were generated in the vicinity of the sampling sites.

The visual inspection included 1) identification and condition of ACM not recorded in the Management Plan as well as the condition of the ACM recorded in the Management Plan; and 2) documentation of the presence of asbestos-containing debris in the 1988 abatement and perimeter areas. These areas were inspected for the presence of debris, as well as residual ACM on the substrate-surface using procedures in accordance with those specified in ASTM Standard E 1368-90.[14] Debris was defined as materials that were of an amount and size (particles greater than 1 mm in diameter) that could be visually identified as to their source.

Sampling Methods

Fixed-Station Area Air Samples

Air samples were collected on open-face, 25-mm-diameter, 0.45-µm-pore-size, mixed cellulose ester (MCE) membrane filters with a 5-µm-pore-size, MCE, backup diffusing filter and cellulose support pad contained in a three-piece cassette. The filter cassettes were positioned approximately 5 feet above the floor on tripods, with the filter face at approximately a 45-degree angle toward the floor. The filter assembly was attached to a 1/6-hp electrically powered vacuum pump operating at a flow rate of approximately 6 L/min. Air volumes ranged from 1488 to 2500 L. At the end of the sampling period, the filters were turned upright before being disconnected from the vacuum pump. They were then stored in this position. The sampling pumps were calibrated with a calibrated precision rotameter immediately before and after sampling.

Bulk Samples

The NJDOH inspector collected bulk samples of suspect ACM (e.g., thermal system insulation, fireproofing, acoustical plaster, ceiling tile, floor tile, and gypsum wallboard) or suspect asbestos-containing debris for laboratory analysis to determine the asbestos content. In school buildings, "asbestos-containing material" is any material that contains more than 1 percent asbestos. A standard coring tool or chipping tool was used to collect in-place materials, hand pickup was used for debris and wipe samples were used for dust. The samples were placed in their respective labeled containers.

Analytical Methods

Air Samples

The MCE filters were prepared by the direct transfer technique and were analyzed in accordance with the nonmandatory transmission electron microscopy (TEM) method, as described in the AHERA Final Rule (40 CFR 763). A sufficient number of grid openings were analyzed for each sample to ensure an analytical sensitivity (the concentration represented by a single structure) of no greater than 0.005 asbestos structure per cubic centimeter (s/cm^3) of air sampled. In addition to the requirements of the nonmandatory TEM method, the specific length and width of each structure were measured and recorded. The samples were prepared and analyzed by U.S. EPA's TEM laboratory in Cincinnati, Ohio.

Bulk Samples

The type and percentage of asbestos in the bulk samples were determined by polarized light microscopy (PLM) and X-ray diffraction (XRD). The samples were prepared and analyzed by the NJDOH's Public Health and Environmental Laboratories in Trenton, New Jersey, in accordance with the "Interim Method for Determination of Asbestos in Bulk Insulation Samples" (EPA 600/M4-82-020).

Statistical Methods

1992 Airborne Asbestos Concentrations

All estimated concentrations were based on the number of asbestos structures counted. If no asbestos structures were counted in a sample, that sample was assigned an estimated concentration of 0 s/cm^3.

Airborne asbestos concentrations measured in each of the three sampling locations (i.e., 1988 abatement area, perimeter area, and outdoors) were characterized for each site by the use of descriptive statistics. The descriptive statistics included the arithmetic mean, minimum and maximum concentrations, and sample size.

Although the 17 schools did not represent a statistical random sample and were likely to differ in abatement history and current status with respect to the presence of asbestos-containing material, the 1992 data were combined across all sites to examine overall trends in airborne asbestos concentrations at these schools. The generalities determined by the overall analysis of these schools should not be extrapolated to the universe of asbestos-abatement sites; rather, they should be limited to these 17 schools.

The arithmetic mean airborne asbestos concentration was first calculated for each of the three sampling locations at each of the 20 abatement sites. This provided a total of 60 estimates of airborne asbestos concentration for analysis. A two-factor analysis of variance (ANOVA) was used to examine overall differences in concentrations measured in the 1988 abatement and perimeter areas and outdoors. The transformation $\ln(x + 0.002)$, where ln is the natural logarithm and x is the mean airborne asbestos concentration, was applied to each measurement before the ANOVA was performed. The transformation was used to make variances more equal and to provide data that are better approximated by a normal distribution. The constant 0.002, a value chosen to be smaller than the majority of analytical sensitivities, was used because some zero values were present (the natural logarithm of zero is undefined). The transformation was used only for the ANOVA analysis; it was not used for any other part of the data analysis (e.g., plots or descriptive statistics). The data were transferred back to the original scale for reporting purposes.

In addition, each site's respective case history contains a separate analysis of the airborne asbestos concentrations measured at that site in 1992. A single-factor ANOVA was used to examine differences between concentrations measured in the 1988 abatement and perimeter areas and outdoors. When overall differences were detected among the three sampling locations, the Tukey multiple comparison procedure was used to evaluate pairwise differences.

1988, 1990, 1991, and 1992 Airborne Asbestos Concentration

Airborne asbestos concentrations measured in 1988, 1990, 1991, and 1992 were compared by using a three-factor ANOVA with Site, Sampling Location, and Year as the main factors. All two-factor interactions were also included in the model. The arithmetic mean concentration was first determined for each combination of year, site, and sampling location. The transformation $\ln(x + 0.002)$, where x is the calculated arithmetic mean concentration and ln is the natural logarithm, was applied to each measurement before the ANOVA was performed. The data were transferred back to the original scale for reporting purposes. In addition, each site's case history contains a separate analysis of airborne asbestos concentrations measured in 1988, 1990, 1991, and 1992 at that site. All statistical comparisons were performed at the 0.05 level of significance. Any reference to a "significant" difference between airborne asbestos concentrations in this report implies that the difference is statistically significant.

SECTION 4

QUALITY ASSURANCE

Sample Chain of Custody

During the study, sample chain-of-custody procedures were an integral part of both the sampling and analytical activities and were followed for all air and bulk samples collected. The field custody procedures documented each sample from the time of its collection until its receipt by the analytical laboratory. Internal laboratory records then documented the custody of the sample through its final disposition.

Standard sample chain-of-custody procedures were used. Each air sample was labeled with a unique project identification number, which was recorded on a sample data sheet along with other information, such as sampling date, location of the sampler, sampling flow rate, sampling start/stop time, and conditions of sampling.

Sample Analysis

Specific quality assurance procedures outlined in the AHERA rule were used to ensure the precision of the collection and analysis of air samples, including filter lot blanks, open and closed field blanks, and repeated sample analyses.

Filter lot blanks, which are samples selected at random from the lot of filters used in this study, were analyzed to determine background asbestos contamination on the filters. Five percent (100 filters) of the total number of filters (2000 filters) from the lot used in this research study were analyzed by the U.S. EPA, RREL TEM laboratory. The filters were prepared by the direct transfer technique and analyzed in accordance with the nonmandatory AHERA TEM method. The TEM analysis of the 100 MCE filters showed a background contamination level of 0 asbestos structures per 10 grid openings on each filter.

Open field blanks are filter cassettes that have been transported to the sampling site, opened for a short time (<30 sec) without air having passed through the filter, and then sent to the laboratory. Closed field blanks are filter cassettes that have been transported to the sampling site and sent to the laboratory without being opened. Two open and one closed field blank were collected at each site. Ten grid openings were examined on each filter. One asbestos structure was detected on an open field blank and one on a closed field blank.

The reproducibility and precision of the TEM analyses were determined by an evaluation of repeated analyses of randomly selected samples. Repeated analyses included replicate and duplicate analyses. A replicate analysis of 17 samples was performed to assess the uniformity of the distribution of asbestos structures on a single grid preparation. A replicate analysis is a second analysis of the same grid performed by the same microscopist as the original analysis. The microscopist uses the same grid preparation but counts different grid openings from those originally read. The results of the replicate analyses are shown in Table 3.

A duplicate sample analysis of seven samples was performed to assess the reproducibility of the TEM analysis and to quantify any analytical variability resulting from the filter preparation procedure. A duplicate analysis is the analysis of a second TEM grid prepared from a different area of the sample filter but analyzed by the same microscopist who performed the original analysis. The results of the duplicate analyses are shown in Table 4.

The coefficient of variation (CV) for the replicate and duplicate analyses was estimated by assuming a lognormal distribution for the data on the original scale and estimating the variance on the log scale. The variance was estimated by the mean square error obtained from a one-way ANOVA of the log-transformed data with the sample identification number as the main factor. 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, a value chosen to be smaller than the minimum analytical sensitivity, was used because many zero values were present. The CVs associated with the replicate and duplicate analyses were 47 and 26 percent, respectively. These CVs are consistent with the range of CVs observed in past EPA studies (0 to 35 percent). The higher CV seen with the replicate analysis was unexpected; one would expect the CV associated with the duplicate analysis to be higher because the duplicate analysis uses a second grid preparation from a different area of the filter. In this case, the higher CV associated with the replicate analysis is probably due to the combined effects of the small number of replicate and duplicate analyses, the high number of zero concentrations, and the method used to calculate the CV. For example, if only the samples with nonzero concentrations were used, the CV for the duplicate analyses (57 percent) is greater than that for the replicate analysis (30 percent).

TABLE 3. DATA SUMMARY FOR REPLICATE ANALYSES[a]

Sample number	Original analysis		Replicate analysis	
	N[b]	s/cm^3	N[b]	s/cm^3
A92-05-O	1	0.003	0	0
A92-06-P	0	0	0	0
D92-01-O	0	0	0	0
D92-04-O	0	0	0	0
D92-08-P	1	0.003	3	0.009
E92-11-A	3	0.008	3	0.008
F92-04-O	1	0.003	1	0.003
I92-05-O	0	0	2	0.006
I92-11-A	0	0	1	0.003
L92-15-A	3	0.007	2	0.005
M92-15-A	2	0.005	0	0
N92-14-A	1	0.002	2	0.005
P92-08-P	0	0	0	0
Q92-15-A	12	0.033	16	0.044
R92-11-A	2	0.005	1	0.003
T92-15-A	0	0	0	0

[a] Different grid openings from the same grid preparation were counted by the same microscopist.

[b] Number of asbestos structures.

TABLE 4. DATA SUMMARY FOR DUPLICATE ANALYSES[a]

Sample number	Original analysis		Duplicate analysis	
	N[b]	s/cm^3	N[b]	s/cm^3
A92-01-O	4	0.011	1	0.003
A92-07-P	0	0	0	0
J92-01-O	0	0	0	0
J92-12-A	0	0	0	0
Q92-14-A	38	0.104	36	0.100
R92-10-P	1	0.003	1	0.003
T92-07-P	0	0	0	0

[a] A second TEM grid preparation was analyzed by the same microscopist.

[b] Number of asbestos structures.

SECTION 5

RESULTS AND DISCUSSION

Site Descriptions

Table 5 presents the abatement history and the remaining ACM at the 20 sites. Since 1988, abatement has occurred at 1 of the 20 sites (Site O) in the 1988 abatement area and at 4 of the 20 sites (A, D, L, and N) in the 1988 perimeter area. At 15 sites, ACM is still present in the 1988 abatement areas; at all of the sites, ACM is still present in the 1988 perimeter areas.

Airborne Asbestos Levels During Occupied Conditions in May 1992

Table 6 presents the mean, minimum, and maximum airborne asbestos concentrations measured at each of the 20 sites in the 17 schools. Figures 1 and 2 illustrate the average airborne asbestos concentrations in the 1988 abatement area and 1988 perimeter area, respectively. Figures 3 and 4 illustrate the average concentration of asbestos structures per square millimeter (s/mm^2) of filter in the 1988 abatement area and 1988 perimeter area, respectively, at each of the 20 sites. Six of the 20 sites (B, D, F, G, H, and Q) showed levels above the AHERA initial screening criterion of 70 s/mm^2 (40 CFR 763) and above the NJDOH-EHS response action criterion of 0.02 s/cm^3 (derived from the AHERA initial screening criterion). Individual measurements of the airborne asbestos concentrations at each of the 20 sites are presented in Appendix A.

A two-factor ANOVA was used to examine overall differences in airborne asbestos concentrations measured at the 20 sites in 1992. When averaged across all sites, airborne asbestos concentrations measured in the 1988 abatement and 1988 perimeter areas were numerically greater than the concentrations measured outdoors, but the difference was not statistically significant ($p = 0.1161$). The overall average concentrations measured in the 1988 abatement and perimeter areas were 0.008 s/cm^3 and 0.007 s/cm^3, respectively. The overall average concentration measured outdoors was 0.003 s/cm^3. Although individually the overall airborne asbestos concentrations measured in the abatement and perimeter areas were not significantly different from concentrations measured outdoors, when combined, the indoor airborne asbestos concentrations at these 20 sites (overall average = 0.008 s/cm^3) were significantly greater ($p = 0.0408$) than concentrations measured outdoors (0.003 s/cm^3).

TABLE 5. ABATEMENT HISTORY AND REMAINING ACM AT THE 20 SITES

Site	Abatement after 1988			Remaining ACM[a]	
	1988 Abatement area	1988 Perimeter area	Material abated[a]	1988 Abatement area	1988 Perimeter area
A	No	Yes	AP, TSI	FT, TSI	FT
B	No	No	-	FT, AP	FT, TSI
C	No	No	-	P (<1%)	P (<1%)
D	No	Yes	TSI	TSI	TSI, FT
E	No	No	-	FT, TSI	FT, TSI
F	No	No	-	TSI	FT, TSI, TR
G	No	No	-	None	FT, P (<1%)
H	No	No	-	AP, TSI	FT, AP, TSI
I	No	No	-	None	FT, TSI
J	No	No	-	TSI	FT
K	No	No	-	FT	FT, TSI
L	No	Yes	FT, TR	FT, TR	FT
M	No	No	-	P (<1%)	P (<1%)
N	No	Yes	AP	FT	FT, TSI
O	Yes	No	TSI	TR	FT, TSI
P	No	No	-	FT, TSI	FT, TSI
Q	No	No	-	FT, AP	FT, TSI
R	No	No	-	FT	FT, TSI
S	No	No	-	FT	FT, TSI
T	No	No	-	None	FT,CT, TSI

[a] AP = Acoustical Plaster
TSI = Thermal System Insulation
FT = Resilient Floor Tile
TR = Transite
CT = Ceiling Tile
P = Wall Plaster

TABLE 6. AIRBORNE ASBESTOS CONCENTRATIONS MEASURED DURING OCCUPIED CONDITIONS AT 20 SITES IN MAY 1992

Site	1988 Abatement area			1988 Perimeter area			Outdoors		
	Asbestos concentration s/cm^3 (N=5)			Asbestos concentration s/cm^3 (N=5)			Asbestos concentration s/cm^3 (N=5)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
A	0.001	0	0.002	0.001	0	0.002	0.008	0	0.017
B	0.044	0.014	0.102	0.438	0.142	1.022	0.001	0	0.003
C	0.008	0	0.021	0.003	0	0.005	0.003	0	0.007
D	0.025	0	0.059	0.001	0	0.003	0	0	0
E	0.009	0.007	0.011	0.007	0.003	0.011	0.004	0	0.010
F	0.036	0.025	0.042	0.037	0.005	0.062	0.002	0	0.008
G	0.148	0.108	0.236	0.011	0	0.033	0.001	0	0.003
H	0.007	0	0.018	0.025	0.006	0.089	0.001	0	0.007
I	0.001	0	0.002	0.001	0	0.003	0.002	0	0.009
J	0.003	0	0.005	0.012	0	0.055	0.001	0	0.003
K	0.007	0	0.017	0.002	0	0.005	0.004	0	0.012
L	0.003	0	0.007	0.002	0	0.005	0	0	0
M[a]	0.003	0	0.005	0.004[b]	0	0.013	0.003	0	0.007
N[c]	0.004	0.002	0.008	0.006	0.003	0.013	0.004	0	0.012

(continued)

TABLE 6 (continued)

Site	1988 Abatement area			1988 Perimeter area			Outdoors		
	Asbestos concentration s/cm^3 (N=5)			Asbestos concentration s/cm^3 (N=5)			Asbestos concentration s/cm^3 (N=5)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
O	0.002	0	0.005	0.001	0	0.003	0.027	0.012	0.047
P	0.003	0	0.010	0.006	0	0.020	0.009[b]	0	0.018
Q[d]	0.053	0.025	0.104	0.438	0.142	1.022	0.001	0	0.003
R	0.001	0	0.005	0.003	0	0.008	0.004	0	0.006
S	0	0	0	0.001	0	0.003	0.007[b]	0	0.020
T	0	0	0	0.001	0	0.003	0.001	0	0.003

[a] Outdoor samples are the same as those collected at Site C (i.e., Site M was the second abatement project at this site).

[b] N = 4.

[c] Outdoor samples are the same as those collected at Site K (i.e., Site N was the second abatement project at this site).

[d] Perimeter and outdoor samples are the same as those collected at Site B (i.e., Site Q was the second abatement project at this school).

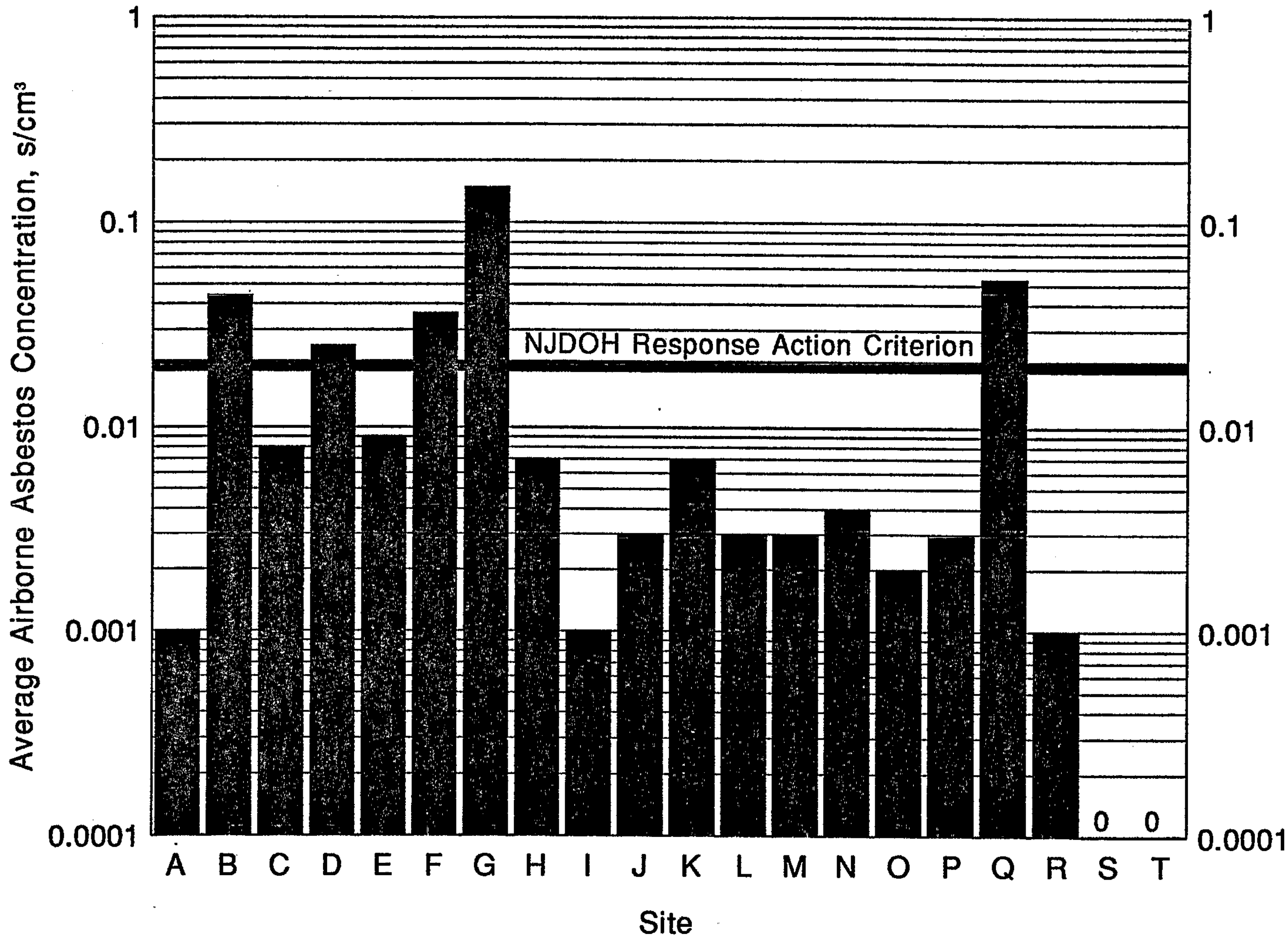

Figure 1. Average airborne asbestos concentrations (s/cm³) in the 1988 abatement area measured during occupied conditions in May 1992.

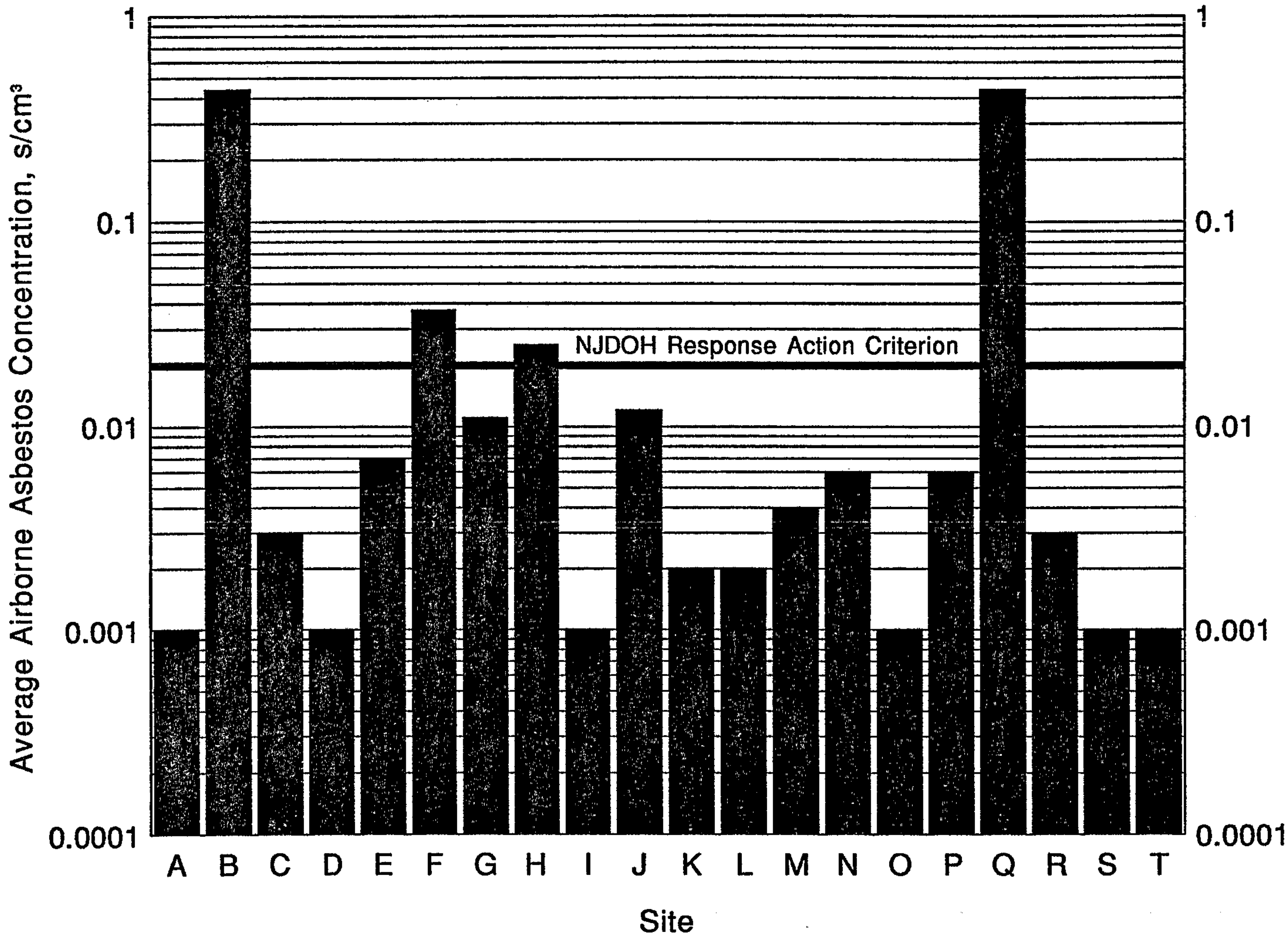

Figure 2. Average airborne asbestos concentrations (s/cm³) in the 1988 perimeter area measured during occupied conditions in May 1992.

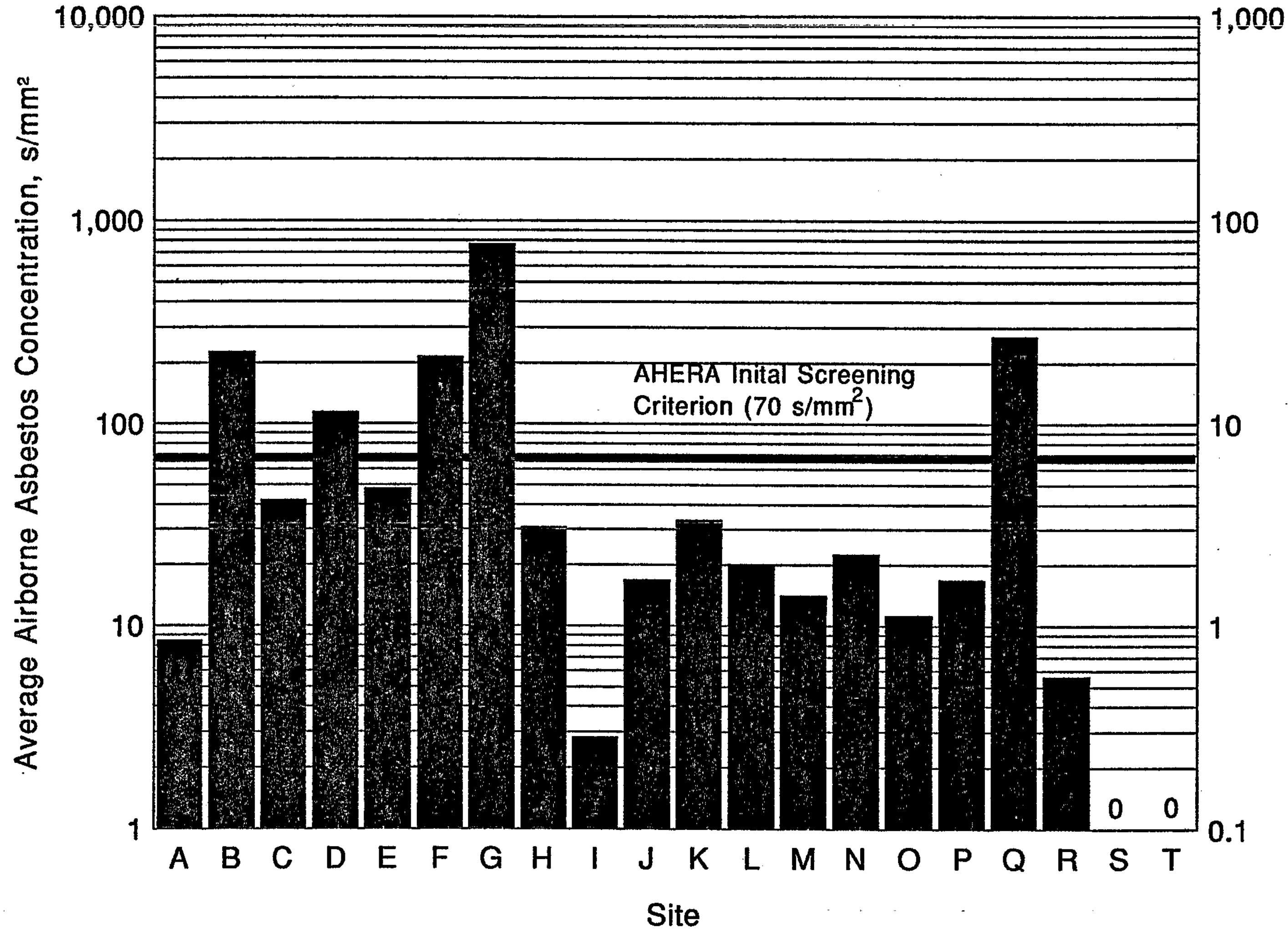

Figure 3. Average concentrations of asbestos structures per square millimeter (s/mm²) in the 1988 abatement area measured during occupied conditions in May 1992.

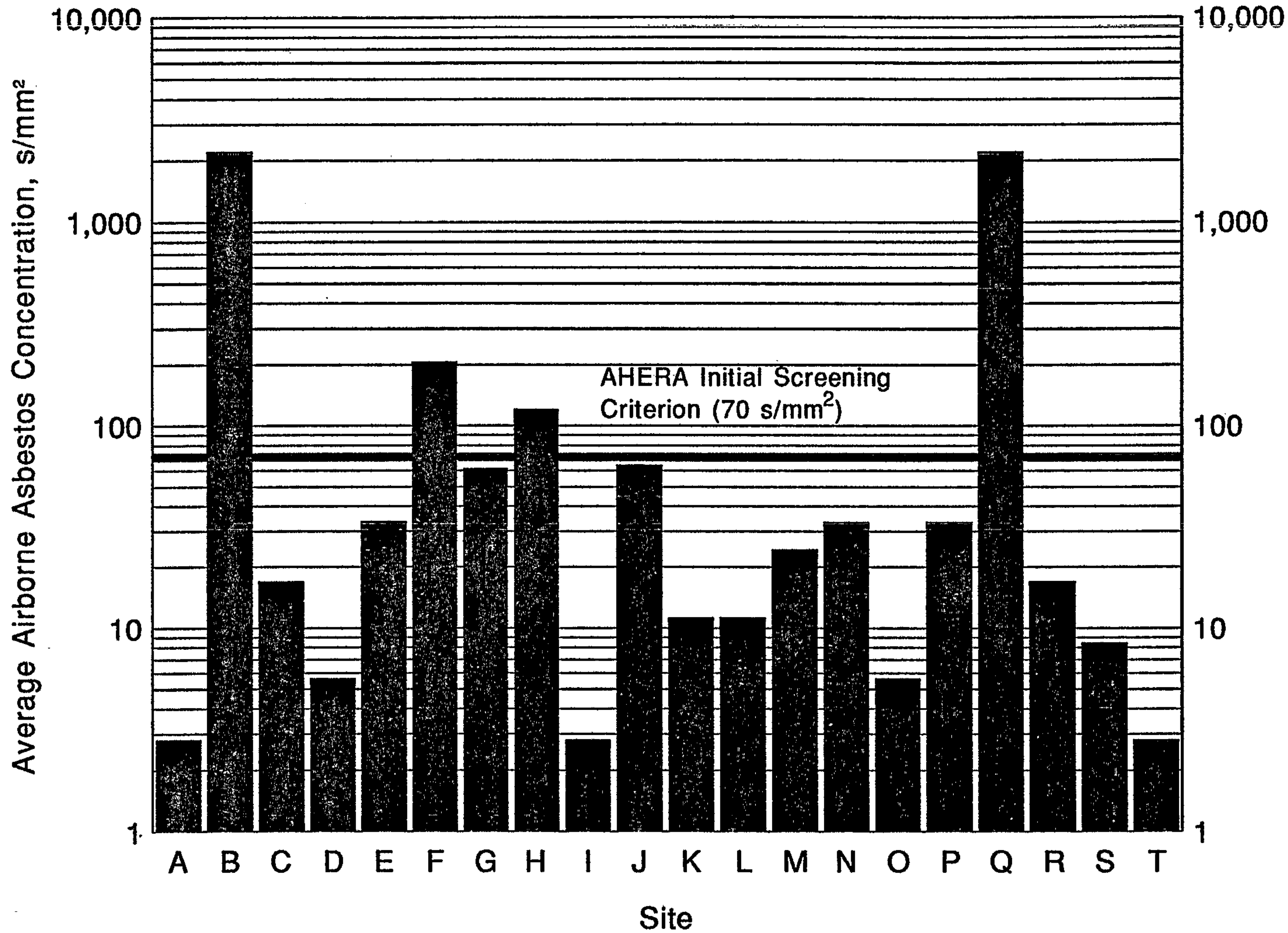

Figure 4. Average concentrations of asbestos structures per square millimeter (s/mm²) in the 1988 perimeter area measured during occupied conditions in May 1992.

Overall Structure Morphology and Length Distributions

Table 7 presents the overall distribution of structure type and morphology from samples collected at the 20 sites. The TEM analysis of 100 samples collected during occupied conditions in the 1988 abatement area, 94 samples collected in the perimeter area, and 83 samples collected outdoors yielded a total of 1552 asbestos structures, of which 99.7 percent were chrysotile asbestos and 0.3 percent were amphibole. Overall, the asbestos structures were primarily fibers (87 percent), and to a lesser extent, matrices, bundles, and clusters. The structures morphology distributions for each site are presented in each site's respective case history in Appendix B.

TABLE 7. OVERALL DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED DURING OCCUPIED CONDITIONS AT 20 SITES IN MAY 1992 (percentages)

Sampling location	Type of asbestos		Structure morphology			
	Chrysotile	Amphibole	Fibers	Bundles	Clusters	Matrices
1988 Abatement area (N = 676)	99.6	0.4	85.1	4.1	1.0	9.7
1988 Perimeter area (N = 754)	99.9	0.1	87.9	2.4	1.1	8.6
Outdoors (N = 122)	100	0	86.9	4.9	0	8.2

Table 8 presents the overall cumulative size distribution of asbestos structures from samples collected at the 20 sites during occupied conditions in May 1992. Overall, less than 1 percent of the measured asbestos structures were greater than 5 µm in length; most of the structures (97 percent) were less than 2 µm in length. The cumulative size distributions of asbestos structures at each site are presented in each site's case history in Appendix B.

NJDOH Inspections

In 1991, NJDOH-EHS conducted an inspection at each of the 17 schools, which represented 20 sites. Each inspection included a review of the school's Asbestos Management Plan relating to the 1988 abatement areas and perimeter areas and a visual inspection of these areas. In July through August 1992, a followup visual inspection was conducted at three schools that represented four sites with elevated airborne asbestos levels (i.e., ≥ 0.02 s/cm^3) based on monitoring conducted in May 1992.

TABLE 8. OVERALL CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED DURING OCCUPIED CONDITIONS AT 20 SITES IN MAY 1992 (percentages)

Sample location	Structure length, µm					
	≤1	≤2	≤3	≤4	≤5	≤10
1988 Abatement area	74.0	95.4	97.9	98.2	98.5	99.9
1988 Perimeter area	73.3	96.7	98.3	98.8	99.5	99.7
Outdoors	81.1	96.7	98.4	99.2	99.2	100

Table 9 presents a summary of the inspections conducted in 1991 and 1992. Appendix B presents a detailed case history of each site. (The data presented in the following subsections were provided to the respective school officials, and each school has reportedly corrected its Asbestos Management Plan accordingly.)

Management Plan Review

At 16 of the 20 sites, the school's Management Plan contained at least one error relating to the areas of the school inspected by the NJDOH-EHS (Table 9). The errors related to material identification or material location.

Fourteen of the sites (A, B, E, F, H, K, L, and N through T) contained at least one ACM not identified in the original AHERA inspection conducted by the school; i.e., the original AHERA inspection did not record the presence of these materials in the school's Management Plan. The ACM identified included thermal system insulation (TSI) on mechanical equipment, pipes, and ventilation ducts; resilient floor tile; gypsum wallboard; Transite® plate; and concrete-masonry block mortar. The most consistently unidentified material was TSI, which was not identified at 14 of the 20 sites inspected. These 14 sites represent 70 percent of the 20 sites and 71 percent of schools (12 of the 17 schools) studied. By comparison, an AHERA evaluation study showed that 82 percent of the school buildings studied had at least one material unidentified in the original AHERA inspection.[11] In both studies, there was a significant percentage of the schools that had errors in the Management Plans regarding identification of ACMs.

At five sites (C, F, H, K, and M), the Management Plan misidentified materials. At three of the sites (C, H, and M) the materials (hard plaster and TSI) did not contain >1 percent asbestos based on bulk sample analysis by the NJDOH-EHS. At one of the sites (F), the ACM identified in the Management Plan was spray-on surfacing

TABLE 9. SUMMARY OF NJDOH-EHS INSPECTIONS AND AIR MONITORING CONDUCTED IN 1991 AND 1992

Observations	Sites[a]																			
	A	B[b]	C	D	E	F[b]	G[b]	H	I	J	K	L	M	N	O	P	Q[b]	R	S	T
ASCM firm that prepared the Management Plan[c]	2	6	1	1	5	5	3	1	4	–[d]	3	5	1	3	1	1	6	1	1	3
Accuracy of Management Plan																				
ACM present, not identified in Plan	●	● O			●	● O		●			●	●		●	●	●	● O	●	●	●
Misidentification of ACM in Plan			●			● O		●			●		●							
Misidentified location of ACM in Plan						● O														
Residual Debris																				
Asbestos-containing debris present from 1988 abatement		● O	●	●	●	● O	● O	●		●					●	●	● O	●	●	●
Other asbestos-containing debris present	●	O			●	● O		●	●	●	●		●		●		O		●	
Asbestos level ≥0.02 s/cm³																				
1991–1988 abatement area		X		X	X	X	X	X			X		X							
1991–1988 perimeter area						X														
1992–1988 abatement area		X		X		X	X										X			
1992–1988 perimeter area		X				X		X									X			
Sites with elevated asbestos levels where potential sources were identified		X		X	X	X	X	X			X		X				X			

[a] ● indicates result of 1991 inspection.
O indicates result of 1992 inspection.
X indicates that the observation was true at that site.

[b] Sites having 1992 inspections.

[c] ASCM firms were assigned numbers to provide anominity.

[d] No Management Plan was prepared. Site J was a community college and was not covered by AHERA.

material, but inspections by NJDOH-EHS showed it to be TSI. At the same site, the Management Plan did not identify the presence of asbestos-containing TSI in the boiler. At one of the sites (K), the school's Management Plan did not identify the resilient floor tile as asbestos-containing.

At one site (F), the Management Plan was in error regarding both the identification and location of an ACM. The Management Plan indicated the presence of spray-on materials in an area where no spray-on materials were present. Actually, TSI was present at this site.

Nine of the 16 sites (B, D through H, K, M, and Q) with Management Plan errors had elevated airborne asbestos levels in either May 1991 or May 1992. At two of these 9 sites (F and K), O&M activities involving ACM that was not identified in the Management Plan may have contributed to the elevated airborne asbestos levels. Site F involved the disturbance of damaged TSI on piping during installation of a fire protection system; and Site K involved the removal of asbestos-containing resilient floor tile. At one site (C) asbestos-containing plaster that was "identified in the Management Plan" was disturbed. This material may have contributed to the elevated levels measured at this site.

Residual Asbestos-Containing Debris

The 1991 and 1992 visual inspections of the 1988 abatement areas revealed that 14 sites had residual debris or dust associated with the 1988 abatement. Each site was inspected to determine the presence of asbestos-containing debris from the 1988 abatement and/or asbestos-containing debris from other activities. The visual inspections revealed the presence of asbestos-containing debris at 18 sites (A through K, M, and O through T) (Table 9). At 14 sites (B through H, J, and O through T) the debris was present in the 1988 abatement area. Eight of these 14 sites (B through D, F, H, Q, S, and T) also failed the AHERA initial screening criterion of 70 s/mm^2 during the 1988 clearance test, which indicated that asbestos-containing debris remained in the abatement area.

The debris identified at the 14 sites was believed to have resulted from the 1988 abatements involving fireproofing, acoustical plaster, ceiling tile, and TSI in these areas. Debris was believed to be from the 1988 abatements based on 1) information from the original abatement specifications, 2) sample analysis, 3) location of the material, and 4) residual debris on the original substrates abated (e.g., pipes). Other asbestos-containing debris present at 12 of the sites (A, B, E, F, H through K, M, O, Q and S) generally resulted from damaged TSI, fireproofing, and acoustical plaster. At one site (B), the debris resulted from efflorescence of concrete-masonry block and/or mortar resulting in a white powdery material along the base of the wall; this debris contained chrysotile asbestos.

Elevated airborne asbestos levels (i.e., ≥0.02 s/cm^3) were measured by EPA/NJDOH in the 1988 abatement area and/or perimeter areas at eight sites in May 1991 (Table 9) and at six sites in 1992 (Tables 6 and 9). The potential sources of the elevated levels were believed to be primarily the debris identified during the NJDOH-EHS visual inspections conducted in 1991 and/or 1992.

The 1991 and 1992 visual inspections of the 1988 abatement areas revealed that 14 sites had debris or dust associated with the 1988 abatement. At six of these 14 sites (B, D, E, G, H, and Q) the debris was considered to be much greater (i.e., "gross debris") than at the eight other sites with minor debris (C, F, J, O, P, R, S, and T). Airborne asbestos levels measured at the six sites with gross debris from the 1988 abatement were significantly higher in both 1991 (0.016 s/cm^3, p = 0.0411) and 1992 (0.029 s/cm^3, p = 0.0086) than those measured at the sites with minor debris (0.004 s/cm^3 and 0.004 s/cm^3, respectively).

In addition, other sources such as floor care maintenance activities (including stripping and spray-buffing of asbestos-containing resilient floor tile[12] and routine vacuuming of carpet[13]) could also contribute to the airborne asbestos levels present in these school buildings.[6]

Response Action Evaluation

1991 Response Action

In May 1991, 8 of the 20 sites (B, D through H, K, and M) had average airborne asbestos levels above 0.02 s/cm^3 (Table 9). In August 1991, EPA/NJDOH conducted followup monitoring at these sites to determine if the elevated levels still existed. Results of the followup monitoring indicated that four sites (F, G, H, and M) showed average levels exceeding 0.02 s/cm^3. The NJDOH-EHS required each of these schools to conduct response actions to reduce the asbestos levels below the 0.02 s/cm^3 criterion. The most appropriate response action was determined by each school and/or their consultant, and included dry-vacuuming of horizontal surfaces with a HEPA-filtered vacuum cleaner, wet-wiping of horizontal surfaces, or encapsulation. Subsequent to response actions by the schools, monitoring conducted by EPA/NJDOH showed that one of the four sites (Site M) had an average airborne asbestos level above 0.02 s/cm^3. Further response actions were required at this site, and NJDOH-EHS collected additional samples. The final results showed levels below 0.02 s/cm^3. Table 10 presents the results of the followup air monitoring in 1991.

1992 Response Action

In May 1992, six sites (B, D, F through H, and Q) had average asbestos levels above 0.02 s/cm^3 (Table 6). The NJDOH-EHS required each of the five schools (representing the six sites) to conduct response actions to reduce the asbestos levels

TABLE 10. FOLLOWUP AIR MONITORING RESULTS AT EIGHT SITES IN 1991

Site	1988 Abatement area			1988 Perimeter area			Outdoors		
	Asbestos concentration, s/cm³ (N=5)			Asbestos concentration, s/cm³ (N=5)			Asbestos concentration, s/cm³ (N=5)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
B	0.018	0	0.064	0.001	0	0.005	0.001	0	0.005
D	0.016	0	0.058	0	0	0	0.001	0	0.005
E	0.005	0	0.025	0.010	0	0.030	0.001	0	0.005
F	0.023	0.014	0.037	0.024	0	0.047	0.004	0	0.010
F[a]	0	0	0	0.003	0	0.008	0.001	0	0.004
G	0.048	0.028	0.080	0.063	0.022	0.181	0.013	0.009	0.015
G[a]	0.010	0	0.044	0.004	0	0.010	0.005	0	0.015
H	0.035	0.006	0.061	0.013	0	0.025	0	0	0
H[a]	0.016	0	0.073	0	0	0	0.001	0	0.005
K	0.004	0	0.006	0.001	0	0.005	0.003	0	0.009
M	0.033	0.008	0.082	0.013	0	0.031	0.001	0	0.004
M[a]	0.001	0	0.005	0.029	0	0.131	0	0	0
M[a]	0.005	0.005	0.005	0	0	0	-[b]	-	-

[a] Post-response action monitoring.

[b] Outdoor samples were not collected.

below the 0.02 s/cm^3 criterion. Subsequent to the response actions at these schools, EPA/NJDOH conducted followup air monitoring to determine the residual levels of airborne asbestos. Based on these results (Table 11), NJDOH-EHS determined that no further response action was required at these schools. One school (Site F) had an average airborne asbestos level above 0.02 s/cm^3. Additional air monitoring following further response action showed final airborne asbestos levels below 0.02 s/cm^3.

TABLE 11. FOLLOWUP AIR MONITORING RESULTS AT SIX SITES IN 1992

Site	1988 Abatement area			1988 Perimeter area		
	Asbestos concentration, s/cm^3 (N=5)			Asbestos concentration, s/cm^3 (N=5)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
B	0.001	0	0.014	0.006	0	0.021
D	0.008	0	0.021	0	0	0
F	-[a]	-[a]	-[a]	0.070[b]	0.028[b]	0.121[b]
G	0.006	0.003	0.012	0.002	0	0.004
H	0.015	0.004	0.029	0.02	0.004	0.034
Q	0.009	0	0.020	0.007	0.003	0.021

[a] Followup monitoring by school's consultant after study period.

[b] Mean of 0.004 s/cm^3 after an additional response action.

Comparison of 1988, 1990, 1991, and 1992 Airborne Asbestos Levels

Table 12 presents the arithmetic mean concentrations of airborne asbestos for all 20 sites measured in the 1988 abatement area, perimeter area, and outdoors during the AHERA clearance phase of the 1988 abatement, during simulated occupancy in 1990, and during occupied conditions in 1991 and 1992. A three-factor ANOVA was used to examine overall differences in airborne asbestos concentrations measured at the 20 sites with site, sampling location, and year as the main factors. The ANOVA results showed that the two-factor interactions were all highly significant ($p = 0.0002$). A significant interaction indicates that the differences between one factor depends on the level of the second factor. For example, a significant interaction between location and year indicates that the differences in airborne asbestos concentrations measured in the three sampling locations (1988 abatement area, perimeter area, and outdoors) varied significantly depending on the year of the sampling. Therefore, it is not appropriate to average across all 4 years to make an overall comparison of sampling location. Similarly, it would not be appropriate to

TABLE 12. MEAN CONCENTRATIONS OF AIRBORNE ASBESTOS MEASURED AT 20 SITES IN 1988, 1990, 1991, AND 1992

	Mean asbestos concentration, s/cm³											
	1988 Abatement area				1988 Perimeter area				Outdoors			
Site	1988	1990	1991	1992	1988	1990	1991	1992	1988	1990	1991	1992
A	0.002	0.007	0.001	0.001	0.001	0.011	0.003	0.001	0	0	0.003	0.008
B	0.016	0.015	0.027	0.044	0.008	0.010	0.012	0.438	0.001	0.001	0.001	0.001
C	0.060	0.001	0.005	0.008	0.002	0.001	0.001	0.003	0.004	0	0.003	0.003
D	0.070	0.001	0.020	0.025	0.062	0.001	0.004	0.001	0.052	0	0.004	0
E	0	0.004	0.037	0.009	0	0.006	0.010	0.007	0	0	0.003	0.004
F	0.024	0.001	0.043	0.036	0.002	0.005	0.036	0.037	0.001	0	0.001	0.002
G	0.007	0.001	0.027	0.148	0.010	0.001	0.005	0.011	0	0.001	0.001	0.001
H	0.016	0	0.030	0.007	0.062	0	0.005	0.025	0.003	0	0.003	0.001
I	0	0.001	0.003	0.001	0	0.011	0.005	0.001	0.005	0.001	0.005	0.002
J	0.004	0	0.003	0.003	0.001	0.003	0	0.012	0.001	0	0.001	0.001
K	0.063	0	0.041	0.007	0.008	0.007	0.003	0.002	0	0.001	0	0.004
L	0.118	0.002	0.006	0.003	0.060	0.001	0.003	0.002	0.004	0	0	0
M[a]	0.322	0	0.023	0.003	0.002	0	0.004	0.004[c]	0.002	0	0.003	0.003
N[b]	0.100	0.007	0.004	0.004	0.003	0.004	0.015[c]	0.006	0.004	0.001	0	0.004

(continued)

TABLE 12 (continued)

Site	Mean asbestos concentration, s/cm³											
	1988 Abatement area				1988 Perimeter area				Outdoors			
	1988	1990	1991	1992	1988	1990	1991	1992	1988	1990	1991	1992
O	0.040	0.001	0.005	0.002	0.003	0.018	0	0.001	0.001	0.001	0.001	0.027
P	0.005	0.005	0.004	0.003	0.007	0	0.001	0.006	0.003	0	0	0.009[c]
Q[d]	0.099	0.019	0.009	0.053	0.055	0.010	0.012	0.438	0.007	0.001	0.001	0.001
R	0.002	0	0.005	0.001	0	0.011	0.001	0.003	0	0.013	0.004	0.004
S	0.012	0.003	0.001	0	0.003	0.001	0.003	0.001	0	0	0.001	0.007
T	0.049	0.001	0.001	0	0.030	0.001	0.001	0.001	0.015	0.005	0	0.001

[a] Outdoor samples are the same as those collected at Site C (i.e., Site M was the second abatement project at this site).

[b] Outdoor samples are the same as those collected at Site K (i.e., Site N was the second abatement project at this site).

[c] N = 4.

[d] Perimeter and outdoor samples are the same as those collected at Site B (i.e., Site Q was the second abatement project at this school).

average across all three sampling locations to make an overall comparison of the yearly averages. Consequently, it was necessary to analyze the data separately for each year, to examine differences between sampling locations. It was also necessary to analyze the data separately for each sampling location to examine differences between the different years. Therefore, a separate two-factor ANOVA was used for each sampling location and for each year.

Comparison of Sampling Locations

A two-factor ANOVA, with Site and Sampling Location as the main factors, was used to examine overall differences between the three sampling locations. Each year was analyzed separately. The results of the ANOVAs are summarized in Table 13.

TABLE 13. COMPARISON OF SAMPLING LOCATIONS FOR AIRBORNE ASBESTOS MEASURED IN 1988, 1990, 1991, AND 1992

Year	ANOVA p-value[a]	Statistically significant differences in airborne asbestos concentrations[b,c,d]
1988	0.0001	A(0.020) P(0.006) O(0.002)
1990	0.0030	P(0.003) A(0.002) O(0.001)
1991	0.0001	A(0.008) P(0.004) O(0.001)
1992	0.1161	P(0.008) A(0.007) O(0.003)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 abatement area; P = 1988 perimeter area; O = Outdoors.

[c] Parenthetical entries are average airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (averages) connected by a line are not significantly different.

1988

The ANOVA results showed significant differences in airborne asbestos concentrations between the three sampling locations (p = 0.0001). Specifically, postabatement airborne asbestos concentrations measured in the 1988 abatement area were significantly greater than those measured in the perimeter area and outdoors. No overall difference existed between airborne asbestos concentrations measured in the perimeter areas and outdoors. The overall average concentrations in the abatement and perimeter areas were 0.020 and 0.006 s/cm^3, respectively. The overall average concentration measured outdoors was 0.002 s/cm^3.

1990

The ANOVA results showed significant differences in airborne asbestos concentrations between the three sampling locations (p = 0.0030). Specifically, the differences in airborne asbestos concentrations measured in the perimeter area were significantly greater than those measured outdoors. All other differences in airborne asbestos concentrations between the three sampling locations were not statistically significant. The overall average airborne asbestos concentrations measured in the 1988 abatement and perimeter areas were 0.002 and 0.003 s/cm^3, respectively. The overall average concentration measured outdoors was 0.001 s/cm^3.

1991

The ANOVA results showed significant differences in airborne asbestos concentrations between the three sampling locations (p = 0.0001). Specifically, the airborne asbestos concentrations measured in the 1988 abatement and perimeter areas were significantly higher than those measured outdoors. The asbestos concentrations measured in the abatement area were significantly greater than those measured in the perimeter area. The overall average concentrations measured in the 1988 abatement and perimeter areas were 0.008 and 0.004 s/cm^3, respectively. The overall average airborne asbestos concentration measured outdoors was 0.001 s/cm^3.

1992

The ANOVA results showed no significant differences in airborne asbestos concentrations measured in the 1988 abatement and perimeter areas and those measured outdoors (p = 0.1161). The overall average airborne asbestos concentrations measured in the 1988 abatement and perimeter areas were 0.008 and 0.007 s/cm^3, respectively. The overall average concentration measured outdoors was 0.003 s/cm^3. Although individually the airborne asbestos concentrations in the abatement and perimeter areas were not significantly different from those measured outdoors, when these concentrations were combined, the indoor airborne asbestos concentration (overall average = 0.008 s/cm^3) was significantly greater than the concentrations measured outdoors.

Comparison of Years

A two-factor ANOVA, with Site and Year as the main factors, was used to examine overall differences between the 4 years of sampling results. Each sampling location was analyzed separately. The results of the ANOVAs are summarized in Table 14.

TABLE 14. COMPARISON OF YEARLY CONCENTRATIONS OF AIRBORNE ASBESTOS

Sampling Location	ANOVA p-value[a]	Statistically significant differences in airborne asbestos concentrations[b,c]
1988 Abatement area	0.0001	1988(0.020) 1991(0.009) 1992(0.007) 1990(0.002)
1988 Perimeter area	0.2725	1992(0.008) 1988(0.006) 1991(0.004) 1990(0.003)
Outdoors	0.0369	1992(0.003) 1988(0.002) 1991(0.002) 1990(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between the years.

[b] Parenthetical entries are average airborne asbestos concentrations (s/cm^3) associated with that year.

[c] Years (averages) connected by a line are not significantly different.

1988 Abatement Area

The ANOVA results showed significant differences between airborne asbestos concentrations measured in 1988, 1990, 1991, and 1992 ($p = 0.0001$). Specifically, airborne asbestos concentrations measured in 1988 (overall average = 0.020 s/cm^3) were significantly greater than those measured in 1990 (overall average = 0.002 s/cm^3) and 1992 (overall average = 0.007 s/cm^3). Additionally, airborne asbestos concentrations measured in 1991 (overall average = 0.009 s/cm^3) were significantly greater than those measured in 1990. All other differences in airborne asbestos concentrations among the 4 years of sampling were not statistically significant.

1988 Perimeter Area

In the 1988 perimeter area, the ANOVA results showed no significant differences between airborne asbestos concentrations measured in 1988, 1990, 1991, and 1992 ($p = 0.2725$). Overall average airborne asbestos concentrations ranged from 0.003 s/cm^3 in 1990 to 0.008 s/cm^3 in 1988.

Outdoors

The ANOVA results showed significant differences in airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 ($p = 0.0369$). Specifically, outdoor airborne asbestos concentrations were significantly greater in

1992 (0.003 s/cm³) than in 1990 (0.001 s/cm³). Outdoor airborne asbestos concentration did not vary significantly in 1988, 1990, and 1991.

General Observations From 1988, 1990, 1991, and 1992 Studies

Table 15 presents an overall summary of the air monitoring results from the four EPA/NJDOH studies conducted during the period of 1988 through 1992. The table also summarizes AHERA clearance test results based on the EPA/NJDOH data, and information regarding the visual inspections conducted at these sites. A summary of important observations made during these studies is presented below.

1988 Preabatement Sampling

Unless all safeguards are properly applied,[3] asbestos removals may elevate airborne levels of asbestos fibers in a building.[1,3] To determine the effect of the abatement on the airborne levels of asbestos structures in a building prior to abatement, preabatement samples were collected in the perimeter area and outdoors at nine schools.[6] The samples were collected under passive building conditions; i.e., there was minimal occupant activity in the building. The airborne asbestos concentrations measured in the perimeter areas (overall average = 0.001 s/cm³) were not significantly different from those measured outdoors (overall average = 0.001 s/cm³). Table 16 presents the average airborne asbestos concentrations measured in the perimeter areas and outdoors in 1988.

Table 17 presents the average airborne asbestos concentrations measured from preabatement through 1992 at nine schools representing 10 sites. Overall, airborne asbestos concentrations measured in the perimeter areas in 1992 and in the postabatement period in 1988 were significantly greater than those measured in the preabatement period in 1988 ($p = 0.0017$). Airborne asbestos concentrations measured in the perimeter area in 1990 and 1991 were not significantly different from those measured in the preabatement period in 1988. The 1992 level at Sites B/Q (0.438 s/cm³) contributed significantly to the overall concentration measured in 1992. In fact, if Sites B/Q are omitted, the only significant difference in airborne asbestos concentrations measured in the perimeter areas was between post-abatement and preabatement concentrations in 1988 ($p = 0.0277$). Specifically, levels were significantly higher, on average, after the abatement than before the abatement at these eight sites.

The specific cause of the elevated, postabatement levels in the perimeter areas in 1988 is uncertain. It is known, however, that the airborne asbestos levels in the perimeter area can be compromised by work practices; breeched containment barriers; air discharges from torn flexible ductwork of air filtration units; inadequate decontamination of tools, equipment, and personnel exiting the containment; or the disturbance of asbestos-containing materials outside of containment area. Outdoor air

TABLE 15. SUMMARY OBSERVATIONS FROM 1988, 1990, 1991, AND 1992 EPA/NJDOH STUDIES

Site	Average airborne asbestos concentration, s/cm³										EPA/NJDOH 1988 AHERA clearance				1991/1992 Visual inspection	
			1988 Abatement area				1988 Perimeter area						AHERA Z-test comparison[e]			
	Preabatement[a]	Pre-final cleaning[b]	1988	1990	1991	1992	1988	1990	1991	1992	No. of NJDOH visual inspections[c]	AHERA initial screening test[d]	Perimeter	Outdoor	Debris present from 1988 abatement	Error in management plan
A	-	0.130	0.002	0.007	0.001	0.001	0.001	0.011	0.003	0.001	4	Pass	Pass	Pass	No	Yes
B	0.001	-	0.016	0.015	0.027	0.044	0.008	0.010	0.012	0.438	3	Fail	Pass	Fail	Yes	Yes
C	0.001	0.405	0.060	0.001	0.005	0.008	0.002	0.001	0.001	0.003	1	Fail	Fail	Fail	Yes	Yes
D	0	-	0.070	0.001	0.020	0.025	0.062	0.001	0.004	0.001	0	Fail	Pass	Pass	Yes	No
E	0.001	0.013	0	0.004	0.037	0.009	0	0.006	0.010	0.007	0	Pass	Pass	Pass	Yes	Yes
F	0.003	0.022	0.024	0.001	0.043	0.036	0.002	0.005	0.036	0.037	0	Fail	Fail	Fail	Yes	Yes
G	0	0.171	0.007	0.001	0.027	0.148	0.010	0.001	0.005	0.011	0	Pass	Pass	Pass	Yes	No
H	-	0.245	0.016	0	0.030	0.007	0.062	0	0.005	0.025	2	Fail	Pass	Pass	Yes	No
I	-	0.116	0	0.001	0.003	0.001	0	0.011	0.005	0.001	4	Pass	Pass	Pass	No	No
J	-	1.711	0.004	0	0.003	0.003	0.001	0.003	0	0.012	0	Pass	Pass	Pass	Yes	-[f]
K	-	0.378	0.063	0	0.041	0.007	0.008	0.007	0.003	0.002	4	Fail	Fail	Fail	No	Yes
L	-	0.894	0.118	0.002	0.006	0.003	0.060	0.001	0.003	0.002	2	Fail	Fail	Fail	No	Yes
M	0.001	0.745	0.322	0	0.023	0.003	0.002	0	0.004	0.004	3	Fail	Fail	Fail	No	Yes
N	-	0.978	0.100	0.007	0.004	0.004	0.003	0.004	0.015	0.006	2	Fail	Fail	Fail	No	Yes
O	-	0.013	0.040	0.001	0.005	0.002	0.003	0.018	0	0.001	2	Pass	Pass	Pass	Yes	Yes
P	0.001	0.230	0.005	0.005	0.004	0.003	0.007	0	0.001	0.006	3	Pass	Pass	Pass	Yes	Yes
Q	0.001	-	0.099	0.019	0.009	0.053	0.055	0.010	0.012	0.438	4	Fail	Fail	Fail	Yes	Yes

(continued)

TABLE 15 (continued)

Site	Average airborne asbestos concentration, s/cm^3										EPA/NJDOH 1988 AHERA clearance				1991/1992 Visual inspection	
			1988 Abatement area				1988 Perimeter area						AHERA Z-test comparison[e]			
	Preabatement[a]	Pre-final cleaning[b]	1988	1990	1991	1992	1988	1990	1991	1992	No. of NJDOH visual inspections[c]	AHERA initial screening test[d]	Perimeter	Outdoor	Debris present from 1988 abatement	Error in management plan
R	-	0.372	0.002	0	0.005	0.001	0	0.011	0.001	0.003	7	Pass	Pass	Pass	Yes	Yes
S	0.001	0.624	0.012	0.003	0.001	0	0.003	0.001	0.003	0.001	3	Fail	Pass	Fail	Yes	Yes
T	0.001	-	0.049	0.001	0.001	0	0.030	0.001	0.001	0.001	2	Fail	Fail	Fail	Yes	Yes

[a] Preabatement samples were not collected at Sites A, H through O, and R; all preabatement samples were collected in perimeter area, except at Site M.

[b] Pre-final cleaning samples were not collected at Sites B, D, Q and T.

[c] NJDOH did not conduct a visual inspection at Sites D, E, F, G, and J.

[d] If the average concentration in the abatement area was less than 70 s/mm^2, the site passed the AHERA initial screening test.

[e] If the average concentration in the abatement area was statistically greater than the average concentration in the perimeter area and/or outdoors, the site failed.

[f] No Asbestos Management Plan was prepared. (Site J was a community college and was not covered by AHERA).

TABLE 16. AVERAGE AIRBORNE ASBESTOS LEVELS MEASURED IN PERIMETER AREAS AND OUTDOORS BEFORE THE 1988 ABATEMENT

Site	Average airborne asbestos level, s/cm^3	
	Perimeter area	Outdoors
B/Q	0.001	0
C	0.001	0.003
D	0	0
E	0.001	0
F	0.003	0
G	0	0
P	0.001	0
S	0.001	0.001
T	0	0.003

TABLE 17. AVERAGE ASBESTOS LEVELS IN PERIMETER AREAS AT SITES WHERE PREABATEMENT SAMPLES WERE COLLECTED

Site	Airborne asbestos levels, s/cm^3				
	Preabatement	1988	1990	1991	1992
B	0.001	0.008	0.010	0.012	0.438
C	0.001	0.002	0.001	0.001	0.003
D	0	0.062	0.001	0.004	0.001
E	0.001	0	0.006	0.010	0.007
F	0.003	0.002	0.005	0.036	0.037
G	0	0.010	0.001	0.005	0.011
P	0.001	0.007	0	0.001	0.006
Q[a]	0.001	0.055	0.010	0.012	0.438
S	0.001	0.003	0.001	0.003	0.001
T	0.001	0.030	0.001	0.001	0.001

[a] Preabatement samples collected in 1988, and samples collected in 1990, 1991, and 1992 are the same as those collected at Site B.

samples are less likely to be affected by these conditions; therefore, it may be more appropriate to use outdoor samples for AHERA Z-test comparisons to clear an abatement project.

1988 NJDOH-EHS Final Clearance Visual Inspection

According to AHERA (40 CFR 763) a final visual inspection must be conducted of the abatement area before final clearance air monitoring takes place. Final visual inspection involves examining the abatement area to determine that the remedial actions have been successfully completed, as indicated by the absence of dust or debris.[14] The basic premise of a final visual inspection is that an area where *residue or debris visible to the unaided eye* is still present is not clean enough for clearance air sampling.[15]

The NJDOH-EHS conducted final visual inspections at 15 of the 20 abatement sites in 1988, including Sites A through C, H through I, and K through T.[5,6] Ten of the 15 sites visually inspected by NJDOH-EHS in 1988 showed no airborne asbestos levels above 0.02 s/cm^3 in 1991 and/or 1992 (Tables 9 and 15). Five of the 15 sites (B, H, K, M, and Q) that underwent NJDOH visual inspections showed airborne asbestos levels above 0.02 s/cm^3 in 1991 and/or 1992 (Tables 9 and 15). Of these five sites, two (Sites M and K) had elevated levels likely attributed to O&M activities that disturbed ACM, two (Sites B and Q) passed the 1988 visual inspection contingent upon the abatement contractor's encapsulating the area above the abated plaster wire-mesh substrate (which did not occur), and at one site (Sites H) the residual material was believed to be beneath the polyethylene sheeting during the visual inspection.

The five sites where NJDOH-EHS did not conduct a visual inspection were Sites D E, F, G, and J. Four of these sites (D through G) showed airborne asbestos levels above 0.02 s/cm^3 in 1991 and/or 1992.

Simulated Occupancy v. Occupied Sampling Conditions

Sampling conditions are an extremely important factor in determining the representativeness of the actual airborne asbestos concentrations measured in a building (e.g., an occupied building versus an unoccupied building). One concern is whether modified aggressive sampling techniques can accurately simulate occupancy conditions. Modified aggressive air sampling involves sweeping only the floors with the exhaust of a 1-hp leaf blower and positioning one stationary fan per 10,000 ft^3 with the air directed toward the ceiling to maintain air movement during sampling.

Modified aggressive air sampling was conducted at the 20 sites in August 1990 to simulate conditions of occupancy.[7] The sampling conducted at the 20 sites in 1991 and 1992 was conducted under conditions of occupancy.[8] At 5 of the 20 sites, the average airborne asbestos concentration in the 1988 abatement area measured during occupied conditions in 1991 was significantly greater than those measured during simulated occupancy in 1990. Also at 3 of the 20 sites, the average airborne asbestos concentration in the 1988 abatement area measured during occupied conditions in 1992 was significantly greater than those measured during simulated occupancy in 1990.

These comparisons appear to support the conclusion that modified aggressive sampling does not effectively simulate conditions of occupancy. This may not be a valid inference, however, because the sampling in 1990 was conducted after the schools had been cleaned for the new school year. Theoretically, this would have resulted in considerably less dust and debris for reentrainment than the amount present at the end of the school year in May of 1991 and 1992. Furthermore, when sampling was required after the May 1991 or 1992 monitoring, a modified aggressive sampling protocol during unoccupied conditions was used to determine if the levels of asbestos were still elevated. The modified aggressive sampling protocol was effective in indicating the presence of elevated levels while the school was unoccupied. After response actions were conducted, the modified aggressive protocol was again utilized and did indicate a decrease in airborne asbestos levels. Whether modified aggressive sampling techniques can accurately simulate occupancy conditions still remains uncertain; therefore further evaluation under similar conditions is required.

1988 AHERA Clearance Discrepancies

AHERA clearance concentration discrepancies were noted between the results of sample analyses reported by the Asbestos Safety Control Monitor (ASCM) firms employed by the school's consultant and those reported independently by EPA/NJDOH.[5,6]

Table 15 summarizes the results of the AHERA initial screening test and the AHERA Z-test for each abatement site based on the EPA/NJDOH samples. Twelve of the 20 sites would have failed the initial screening test had the samples collected by EPA/NJDOH been used. Ten of the 12 sites that would have failed the initial screening test had the EPA/NJDOH data been used would have subsequently failed the AHERA Z-test based on the outdoor concentrations in the comparison. The other two sites (D and H) would have passed the AHERA Z-test, however, relatively high levels of airborne asbestos were present at these sites after the 1988 abatement. (The reason(s) for these elevated levels were not apparent.) The remaining eight sites would have passed both the initial screening test and the Z-test regardless of whether outdoor or perimeter levels were used in the Z-test comparison.

The choice of either the perimeter area outside the work area but inside the building or the outdoor air as the "outside" reference point in the AHERA Z-test would have affected the outcome of the clearance comparison at Sites B and S based on

EPA/NJDOH results. In each case, the site would have passed the Z-test if the perimeter values had been used and failed if the outdoor levels had been used in the comparison. The perimeter area outside the work area can be affected by work practices that may contaminate other areas inside the building, by a breach in the critical barriers surrounding the work area, by the air-filtration systems (e.g., torn ductwork passing through adjacent building areas), or by preexisting ACM in the area. Outdoor samples are less likely to be affected by these conditions, and their use in the clearance comparison would generally provide a more stringent comparison.

AHERA Sampling and Analytical Practices

Specific sampling and analytical requirements for conducting clearance air monitoring are presented in the AHERA Final Rule (40 CFR Part 763). Observations made during the 1988 EPA/NJDOH research study indicated that the AHERA sampling and analytical requirements and recommendations are not completely understood and followed by consultants conducting the clearance air monitoring.[5,6] The following clearance air sampling and analytical practices were observed:

- Fewer than the required five clearance air samples inside the abatement area were collected at two sites.
- Improper sampling media was used to collect clearance air samples, i.e., filter pore size at three sites and filter type at two sites.
- Recommended air sampling flow rates were exceeded at two sites.
- Phase contrast microscopy was improperly used to clear one site.
- Eight of the 20 abatement sites failed to meet the EPA-recommended drying time of 24 hours after completing final cleaning and before conducting final clearance air monitoring.
- Nineteen of the 20 abatement sites used aggressive air sampling techniques. Fourteen of these 19 sites failed to meet the EPA-recommended aggressive air sweeping rate of at least 5 minutes per 1000 square feet of floor area.
- Fifteen of the 20 abatement sites failed to use the number of circulating fans recommended by AHERA during final clearance air monitoring. No circulating fans were used at eight of the sites.

Final Cleaning Practices

Upon completion of the abatement process, the work area must be cleaned in preparation for its restoration to normal use. Various work procedures and practices are used. The ultimate purpose of each is to ensure that postabatement concentrations of asbestos fibers are at or below the concentrations present before the abatement work began and that they are in compliance with the final clearance requirements under the AHERA final rule.

During the 1988 EPA/NJDOH study,[5] final cleaning practices and procedures were documented at each of the 20 abatement projects. Final cleaning practices tended to be similar among abatement contractors. The sequence of cleaning activities depended on the surface from which the asbestos was removed and the physical structure of the work site. Meticulous attention to detail in cleaning practices is important to a successful final cleaning.

Airborne asbestos concentrations were measured before the final cleaning phase at 16 of the abatement sites in 1988. Table 18 summarizes the concentrations measured at these sites. Average airborne asbestos concentrations ranged from 0 to 1.5 s/cm^3. Fourteen of the 16 sites showed an average level above 0.02 s/cm^3.

TABLE 18. AIRBORNE ASBESTOS CONCENTRATIONS MEASURED BEFORE FINAL CLEANING OF ABATEMENT AREA IN 1988

Site[a]	Airborne asbestos concentration, s/cm^3		
	Average	Minimum	Maximum
A	0.123	0.059	0.187
B	-	-	-
C	0.378	0.010	1.403
D	-	-	-
E	0.010	0	0.046
F	0.025	0.005	0.065
G	0	0	0
H	0.245	0.064	0.477
I	0.116	0.035	0.212
J	1.491	1.163	2.773
K	0.373	0.276	0.426
L	0.894	0.567	1.469
M	0.654	0.349	1.410
N	1.021	0.561	1.440
O	0.011	0	0.025
P	0.257	0.102	0.368
Q	-	-	-
R	0.329	0.042	0.587
S	0.624	0.151	1.198
T	-	-	-

[a] No samples were collected before final cleaning at Sites B, D, Q, and T.

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APPENDIX A

INDIVIDUAL ESTIMATES OF AIRBORNE ASBESTOS CONCENTRATIONS FOUR YEARS AFTER ABATEMENT (1992) AT 20 SITES

APPENDIX A
INDIVIDUAL ESTIMATES OF AIRBORNE ASBESTOS CONCENTRATIONS FOUR YEARS AFTER ABATEMENT (IN 1992) AT 20 SITES

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	Concentration s/mm²	Air Volume, L
A	05/21/92	A92-11-A	Previously abated area	0.002	14	2309
A	05/21/92	A92-12-A	Previously abated area	0	0	2204
A	05/21/92	A92-13-A	Previously abated area	0.002	14	2197
A	05/21/92	A92-14-A	Previously abated area	0	0	2164
A	05/21/92	A92-15-A	Previously abated area	0.002	14	2244
A	05/21/92	A92-01-O	Outdoors	0.011	64	2152
A	05/21/92	A92-01-OD	Duplicate analysis of A92-01-O	0.003	16	2152
A	05/21/92	A92-02-O	Outdoors	0	0	2195
A	05/21/92	A92-03-O	Outdoors	0.017	95	2216
A	05/21/92	A92-04-O	Outdoors	0.008	48	2188
A	05/21/92	A92-05-O	Outdoors	0.003	16	2146
A	05/21/92	A92-05-OR	Replicate analysis of A92-05-O	0	0	2146
A	05/21/92	A92-18-CB	Closed field blank	-	0	0
A	05/21/92	A92-06-P	Perimeter area	0	0	2297
A	05/21/92	A92-06-PR	Replicate analysis of A92-06-P	0	0	2297
A	05/21/92	A92-07-P	Perimeter area	0	0	2346
A	05/21/92	A92-07-PD	Duplicate analysis of A92-07-P	0	0	2346
A	05/21/92	A92-08-P	Perimeter area	0.002	14	2195
A	05/21/92	A92-09-P	Perimeter area	0	0	2238
A	05/21/92	A92-10-P	Perimeter area	0	0	2364
B	05/14/92	B92-11-A	Previously abated area	0.102	528	1995
B	05/14/92	B92-12-A	Previously abated area	0.014	69	1976
B	05/14/92	B92-13-A	Previously abated area	0.030	153	1968
B	05/14/92	B92-14-A	Previously abated area	0.038	194	1995
B	05/14/92	B92-15-A	Previously abated area 0.035	181	1995	
B	05/14/92	BQ92-01-O	Outdoors	0	0	1943
B	05/14/92	BQ92-02-O	Outdoors	0	0	1909
B	05/14/92	BQ92-03-O	Outdoors	0	0	1902
B	05/14/92	BQ92-04-O	Outdoors	0.003	14	1909
B	05/14/92	BQ92-05-O	Outdoors	0	0	1902
B	05/14/92	B92-16-OB	Open field blank	-	0	0
B	05/14/92	BQ92-17OB	Open field blank	-	0	0
B	05/14/92	BQ92-18CB	Closed field blank	-	0	0
B	05/14/92	BQ92-06-P	Perimeter area	0.142	736	2000
B	05/14/92	BQ92-07-P	Perimeter area	0.306	1528	1922
B	05/14/92	BQ92-08-P	Perimeter area	0.284	1403	1903
B	05/14/92	BQ92-09-P	Perimeter area	0.434	2130	1890
B	05/14/92	BQ92-10-P	Perimeter area	1.022	5148	1939
B	07/16/92	BQ-792-11A	Previously abated area	0.004	16	1549
B	07/16/92	BQ-792-13A	Previously abated area	0	0	1435
B	07/16/92	BQ-792-14A	Previously abated area	0	0	1930
B	07/16/92	BQ-792-15A	Previously abated area	0	0	1787
B	07/16/92	BQ-792-16OB	Open field blank	-	13	0
B	07/16/92	BQ-792-17OB	Open field blank	-	0	0

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm^3	s/mm^2	Air Volume, L
B	07/16/92	BQ-792-18CB	Closed field blank	-	0	0
B	07/16/92	BQ-792-06P	Perimeter area	0.021	94	1698
B	07/16/92	BQ-792-07P	Perimeter area	0.004	16	1633
B	07/16/92	BQ-792-08P	Perimeter area	0	0	2520
B	07/16/92	BQ-792-09P	Perimeter area	0	0	1778
B	07/16/92	BQ-792-10P	Perimeter area	0.003	16	2115
B	08/24/92	B892-16OB	Open field blank	-	0	0
B	08/24/92	B892-11A	Previously abated area	0.008	32	1531
B	08/24/92	B892-12A	Previously abated area	0.004	16	1579
B	08/24/92	B892-13A	Previously abated area	0.004	16	1467
B	08/24/92	B892-14A	Previously abated area	0.018	63	1356
B	08/24/92	B892-15A	Previously abated area	0	0	1514
C	05/14/92	C92-11-A	Previously abated area	0.008	42	2056
C	05/14/92	C92-12-A	Previously abated area	0.021	111	2062
C	05/14/92	C92-13-A	Previously abated area	0.010	56	2124
C	05/14/92	C92-14-A	Previously abated area	0	0	1974
C	05/14/92	C92-15-A	Previously abated area	0	0	2140
C	05/14/92	C92-01-O	Outdoors	0	0	1767
C	05/14/92	C92-02-O	Outdoors	0.006	32	1887
C	05/14/92	C92-03-O	Outdoors	0.007	32	1815
C	05/14/92	C92-04-O	Outdoors	0	0	1851
C	05/14/92	C92-05-O	Outdoors	0	0	1898
C	05/14/92	C92-16-OB	Open field blank	-	0	0
C	05/14/92	C92-06-P	Perimeter area	0.005	28	2218
C	05/14/92	C92-07-P	Perimeter area	0.003	14	2037
C	05/14/92	C92-08-P	Perimeter area	0.003	14	2115
C	05/14/92	C92-09-P	Perimeter area	0	0	2052
C	05/14/92	C92-10-P	Perimeter area	0.005	28	2011
D	05/13/92	D92-11-A	Previously abated area	0.050	222	1704
D	05/13/92	D92-12-A	Previously abated area	0.008	42	1988
D	05/13/92	D92-13-A	Previously abated area	0	0	1776
D	05/13/92	D92-14-A	Previously abated area	0.006	28	1933
D	05/13/92	D92-15-A	Previously abated area	0.059	278	1810
D	05/13/92	D92-01-O	Outdoors	0	0	1805
D	05/13/92	D92-01-OR	Replicate analysis of D92-01-O	0	0	1805
D	05/13/92	D92-02-O	Outdoors	0	0	1830
D	05/13/92	D92-03-O	Outdoors	0	0	1854
D	05/13/92	D92-04-O	Outdoors	0	0	1817
D	05/13/92	D92-04-OR	Replicate analysis of D92-04-O	0	0	1817
D	05/13/92	D92-05-O	Outdoors	0	0	1867
D	05/13/92	D92-16-OB	Open field blank	-	0	0
D	05/13/92	D92-17-OB	Open field blank	-	0	0
D	05/13/92	D92-18-CB	Closed field blank	-	0	0
D	05/13/92	D92-06-P	Perimeter area	0	0	2012
D	05/13/92	D92-07-P	Perimeter area	0	0	2083

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	s/mm²	Air Volume, L
D	05/13/92	D92-08-P	Perimeter area	0.003	14	1796
D	05/13/92	D92-08-PR	Replicate analysis of D92-08-P	0.009	42	1796
D	05/13/92	D92-09-P	Perimeter area	0	0	2122
D	05/13/92	D92-10-P	Perimeter area	0.003	14	1966
D	08/18/92	D892-16OB	Open field blank	-	0	0
D	08/18/92	D892-11A	Previously abated area	0	0	1001
D	08/18/92	D892-12A	Previously abated area	0.016	56	1339
D	08/18/92	D892-13A	Previously abated area	0	0	1360
D	08/18/92	D892-14A	Previously abated area	0.021	62	1135
D	08/18/92	D892-15A	Previously abated area	0.004	14	1510
D	08/18/92	D892-06P	Perimeter area	0	0	1366
D	08/18/92	D892-07P	Perimeter area	0	0	1295
D	08/18/92	D892-08P	Perimeter area	0	0	1393
D	08/18/92	D892-09P	Perimeter area	0	0	1558
D	08/18/92	D892-10P	Perimeter area	0	0	1474
E	05/12/92	E92-11-A	Previously abated area	0.008	42	2016
E	05/12/92	E92-11-AR	Replicate analysis of E92-11-A	0.008	42	2016
E	05/12/92	E92-12-A	Previously abated area	0.008	42	2127
E	05/12/92	E92-13-A	Previously abated area	0.007	42	2177
E	05/12/92	E92-14-A	Previously abated area	0.010	56	2175
E	05/12/92	E92-15-A	Previously abated area	0.011	56	2019
E	05/12/92	E92-01-O	Outdoors	0	0	1899
E	05/12/92	E92-02-O	Outdoors	0.010	48	1893
E	05/12/92	E92-03-O	Outdoors	0.003	16	1867
E	05/12/92	E92-04-O	Outdoors	0.007	32	1860
E	05/12/92	E92-05-O	Outdoors	0	0	1854
E	05/12/92	E92-06-P	Perimeter area	0.011	56	1948
E	05/12/92	E92-07-P	Perimeter area	0.005	28	1991
E	05/12/92	E92-08-P	Perimeter area	0.003	14	2040
E	05/12/92	E92-09-P	Perimeter area	0.008	42	1915
E	05/12/92	E92-10-P	Perimeter area	0.005	28	1979
F	05/12/92	F92-11-A	Previously abated area	0.034	208	2331
F	05/12/92	F92-12-A	Previously abated area	0.042	250	2275
F	05/12/92	F92-13-A	Previously abated area	0.038	222	2258
F	05/12/92	F92-14-A	Previously abated area	0.025	153	2373
F	05/12/92	F92-15-A	Previously abated area	0.040	236	2287
F	05/12/92	F92-01-O	Outdoors	0	0	2117
F	05/12/92	F92-02-O	Outdoors	0.002	14	2183
F	05/12/92	F92-03-O	Outdoors	0	0	2164
F	05/12/92	F92-04-O	Outdoors	0.003	14	2115
F	05/12/92	F92-04-OR	Replicate analysis of F92-04-O	0.003	14	2115
F	05/12/92	F92-05-O	Outdoors	0.007	42	2146
F	05/12/92	F92-16-OB	Open field blank	-	0	0
F	05/12/92	F92-17-OB	Open field blank	-	0	0
F	05/12/92	F92-18-CB	Closed field blank	-	0	0

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	Concentration s/mm²	Air Volume, L
F	05/12/92	F92-06-P	Perimeter area	0.039	222	2177
F	05/12/92	F92-07-P	Perimeter area	0.061	347	2183
F	05/12/92	F92-08-P	Perimeter area	0.017	79	1838
F	05/12/92	F92-09-P	Perimeter area	0.005	28	2171
F	05/12/92	F92-10-P	Perimeter area	0.062	349	2186
F	09/01/92	F892-17OB	Open field blank	-	0	0
F	09/01/92	F892-06P	Perimeter area	0.098	306	1195
F	09/01/92	F892-07P	Perimeter area	0.121	417	1325
F	09/01/92	F892-08P	Perimeter area	0.032	111	1324
F	09/01/92	F892-10P	Perimeter area	0.028	97	1333
G	05/18/92	G92-11-A	Previously abated area	0.146	764	2011
G	05/18/92	G92-12-A	Previously abated area	0.136	708	1999
G	05/18/92	G92-13-A	Previously abated area	0.236	1222	1993
G	05/18/92	G92-14-A	Previously abated area	0.111	569	1967
G	05/18/92	G92-15-A	Previously abated area	0.108	556	1980
G	05/18/92	G92-01-O	Outdoors	0.003	14	2048
G	05/18/92	G92-02-O	Outdoors	0	0	2048
G	05/18/92	G92-03-O	Outdoors	0	0	2056
G	05/18/92	G92-04-O	Outdoors	0	0	2056
G	05/18/92	G92-05-O	Outdoors	0	0	2030
G	05/18/92	G92-16-OB	Open field blank	-	11	0
G	05/18/92	G92-16-OBR	Replicate analysis of G92-16-OB	-	0	0
G	05/18/92	G92-17-OB	Open field blank	-	0	0
G	05/18/92	G92-18-CB	Closed field blank	-	0	0
G	05/18/92	G92-06-P	Perimeter area	0.033	181	2108
G	05/18/92	G92-07-P	Perimeter area	0.005	28	2073
G	05/18/92	G92-08-P	Perimeter area	0.013	69	2079
G	05/18/92	G92-09-P	Perimeter area	0	0	2091
G	05/18/92	G92-10-P	Perimeter area	0.005	28	2017
G	08/27/92	G892-11A	Previously abated area	0.012	42	1333
G	08/27/92	G892-12A	Previously abated area	0.004	14	1333
G	08/27/92	G892-13A	Previously abated area	0.008	28	1308
G	08/27/92	G892-14A	Previously abated area	0.003	14	1746
G	08/27/92	G892-15A	Previously abated area	0.004	14	1375
G	08/27/92	G892-06P	Perimeter area	0	0	1571
G	08/27/92	G892-07P	Perimeter area	0	0	1314
G	08/27/92	G892-08P	Perimeter area	0	0	1342
G	08/27/92	G892-09P	Perimeter area	0.004	16	1589
G	08/27/92	G892-10P	Perimeter area	0.004	14	1279
H	05/13/92	H92-11-A	Previously abated area	0	0	1814
H	05/13/92	H92-12-A	Previously abated area	0.003	14	1826
H	05/13/92	H92-13-A	Previously abated area	0	0	1911
H	05/13/92	H92-14-A	Previously abated area	0.009	42	1802
H	05/13/92	H92-15-A	Previously abated area	0.018	83	1777
H	05/13/92	H92-01-O	Outdoors	0	0	1776

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm^3	Concentration s/mm^2	Air Volume, L
H	05/13/92	H92-02-O	Outdoors	0.007	32	1723
H	05/13/92	H92-03-O	Outdoors	0	0	1759
H	05/13/92	H92-04-O	Outdoors	0	0	1752
H	05/13/92	H92-05-O	Outdoors	0	0	1717
H	05/13/92	H92-16-OB	Open field blank	-	0	0
H	05/13/92	H92-17-OB	Open field blank	-	0	0
H	05/13/92	H92-18-CB	Closed field blank	-	0	0
H	05/13/92	H92-06-P	Perimeter area	0.006	28	1869
H	05/13/92	H92-07-P	Perimeter area	0.018	83	1820
H	05/13/92	H92-08-P	Perimeter area	0.009	42	1832
H	05/13/92	H92-09-P	Perimeter area	0.006	28	1826
H	05/13/92	H92-10-P	Perimeter area	0.089	417	1795
H	08/25/92	H892-16OB	Open field blank	-	0	0
H	08/25/92	H892-11A	Previously abated area	0.004	14	1332
H	08/25/92	H892-12A	Previously abated area	0.020	69	1362
H	08/25/92	H892-13A	Previously abated area	0.029	97	1290
H	08/25/92	H892-14A	Previously abated area	0.016	56	1342
H	08/25/92	H892-15A	Previously abated area	0.008	28	1380
H	08/25/92	H892-06P	Perimeter area	0.034	127	1456
H	08/25/92	H892-07P	Perimeter area	0.021	79	1457
H	08/25/92	H892-08P	Perimeter area	0.021	79	1477
H	08/25/92	H892-09P	Perimeter area	0.004	16	1408
H	08/25/92	H892-10P	Perimeter area	0.028	97	1324
I	05/15/92	I92-11-A	Previously abated area	0	0	2171
I	05/15/92	I92-11-AR	Replicate analysis of I92-11-A	0.002	14	2171
I	05/15/92	I92-12-A	Previously abated area	0.002	14	2198
I	05/15/92	I92-13-A	Previously abated area	0	0	2231
I	05/15/92	I92-14-A	Previously abated area	0	0	2213
I	05/15/92	I92-15-A	Previously abated area	0	0	2225
I	05/15/92	I92-01-O	Outdoors	0.003	16	2058
I	05/15/92	I92-02-O	Outdoors	0	0	2052
I	05/15/92	I92-03-O	Outdoors	0.009	48	2058
I	05/15/92	I92-04-O	Outdoors	0	0	2031
I	05/15/92	I92-05-O	Outdoors	0	0	2009
I	05/15/92	I92-05-OR	Replicate analysis of I92-05-O	0.006	32	2009
I	05/15/92	I92-16-OB	Open field blank	-	0	0
I	05/15/92	I92-17-OB	Open field blank	-	0	0
I	05/15/92	I92-18-CB	Closed field blank	-	0	0
I	05/15/92	I92-06-P	Perimeter area	0	0	2092
I	05/15/92	I92-07-P	Perimeter area	0.003	14	2086
I	05/15/92	I92-08-P	Perimeter area	0	0	2094
I	05/15/92	I92-09-P	Perimeter area	0	0	2106
I	05/15/92	I92-10-P	Perimeter area	0	0	2117
J	05/15/92	J92-11-A	Previously abated area	0.002	14	2173
J	05/15/92	J92-12-A	Previously abated area	0	0	2216

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm^3	s/mm^2	Air Volume, L
J	05/15/92	J92-12-AD	Duplicate analysis of J92-12-A	0	0	2216
J	05/15/92	J92-13-A	Previously abated area	0.002	14	2161
J	05/15/92	J92-14-A	Previously abated area	0.005	28	2182
J	05/15/92	J92-15-A	Previously abated area	0.005	28	2092
J	05/15/92	J92-01-O	Outdoors	0	0	2101
J	05/15/92	J92-02-O	Outdoors	0	0	2101
J	05/15/92	J92-03-O	Outdoors	0.003	16	2163
J	05/15/92	J92-04-O	Outdoors	0.003	16	2080
J	05/15/92	J92-05-O	Outdoors	0	0	2142
J	05/15/92	J92-16-OB	Open field blank	-	0	0
J	05/15/92	J92-06-P	Perimeter area	0	0	2128
J	05/15/92	J92-07-P	Perimeter area	0.002	14	2142
J	05/15/92	J92-08-P	Perimeter area	0.055	292	2056
J	05/15/92	J92-09-P	Perimeter area	0.002	14	2163
J	05/15/92	J92-10-P	Perimeter area	0	0	2191
J	05/18/92	J92-01-OD	Duplicate analysis of J92-01-O	0	0	2101
K	05/11/92	K92-11-A	Previously abated area	0.017	97	2229
K	05/11/92	K92-12-A	Previously abated area	0.011	42	1505
K	05/11/92	K92-13-A	Previously abated area	0.004	14	1488
K	05/11/92	K92-14-A	Previously abated area	0	0	2124
K	05/11/92	K92-15-A	Previously abated area	0.003	14	2113
K	05/11/92	KN92-01-O	Outdoors	0.012	64	2088
K	05/11/92	KN92-02-O	Outdoors	0.006	32	2109
K	05/11/92	KN92-03-O	Outdoors	0	0	2109
K	05/11/92	KN92-04-O	Outdoors	0	0	2109
K	05/11/92	KN92-05-O	Outdoors	0	0	2103
K	05/11/92	K92-16-OB	Open field blank	-	0	0
K	05/11/92	KN92-17OB	Open field blank	-	0	0
K	05/11/92	KN92-18CB	Closed field blank	-	11	0
K	05/11/92	K92-06-P	Perimeter area	0.004	28	2399
K	05/11/92	K92-07-P	Perimeter area	0	0	2343
K	05/11/92	K92-08-P	Perimeter area	0.005	28	2341
K	05/11/92	K92-09-P	Perimeter area	0	0	2500
K	05/11/92	K92-10-P	Perimeter area	0	0	2328
L	05/20/92	L92-11-A	Previously abated area	0.002	14	2290
L	05/20/92	L92-12-A	Previously abated area	0.005	28	2250
L	05/20/92	L92-13-A	Previously abated area	0.002	14	2154
L	05/20/92	L92-14-A	Previously abated area	0	0	2294
L	05/20/92	L92-15-A	Previously abated area	0.007	42	2297
L	05/20/92	L92-15-AR	Replicate analysis of L92-15-A	0.005	28	2297
L	05/20/92	L92-01-O	Outdoors	0	0	2241
L	05/20/92	L92-02-O	Outdoors	0	0	2154
L	05/20/92	L92-03-O	Outdoors	0	0	2213
L	05/20/92	L92-04-O	Outdoors	0	0	2219
L	05/20/92	L92-05-O	Outdoors	0	0	2213

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	Concentration s/mm²	Air Volume, L
L	05/20/92	L92-16-OB	Open field blank	-	0	0
L	05/20/92	L92-17-OB	Open field blank	-	0	0
L	05/20/92	L92-18-CB	Closed field blank	-	0	0
L	05/20/92	L92-06-P	Perimeter area	0.002	14	2250
L	05/20/92	L92-07-P	Perimeter area	0.005	28	2272
L	05/20/92	L92-08-P	Perimeter area	0	0	2278
L	05/20/92	L92-09-P	Perimeter area	0.002	14	2216
L	05/20/92	L92-10-P	Perimeter area	0	0	2256
M	05/14/92	M92-11-A	Previously abated area	0.003	14	2005
M	05/14/92	M92-12-A	Previously abated area	0.003	14	1999
M	05/14/92	M92-13-A	Previously abated area	0	0	2063
M	05/14/92	M92-14-A	Previously abated area	0.003	14	1810
M	05/14/92	M92-15-A	Previously abated area	0.005	28	1967
M	05/14/92	M92-15-AR	Replicate analysis of M92-15-A	0	0	1967
M	05/14/92	M92-16-OB	Open field blank	-	0	0
M	05/14/92	M92-17-OB	Open field blank	-	0	0
M	05/14/92	M92-18-CB	Closed field blank	-	0	0
M	05/14/92	M92-06-P	Perimeter area	0	0	1983
M	05/14/92	M92-08-P	Perimeter area	0.005	28	2128
M	05/14/92	M92-09-P	Perimeter area	0	0	2005
M	05/14/92	M92-10-P	Perimeter area	0.013	69	2113
N	05/11/92	N92-11-A	Previously abated area	0.003	14	2115
N	05/11/92	N92-12-A	Previously abated area	0.008	42	2074
N	05/11/92	N92-13-A	Previously abated area	0.003	14	2109
N	05/11/92	N92-14-A	Previously abated area	0.002	14	2332
N	05/11/92	N92-14-AR	Replicate analysis of N92-14-A	0.005	28	2332
N	05/11/92	N92-15-A	Previously abated area	0.005	28	2299
N	05/11/92	N92-16-OB	Open field blank	-	0	0
N	05/11/92	N92-06-P	Perimeter area	0.013	69	2115
N	05/11/92	N92-07-P	Perimeter area	0.003	14	2086
N	05/11/92	N92-08-P	Perimeter area	0.003	14	2111
N	05/11/92	N92-09-P	Perimeter area	0.007	42	2199
N	05/11/92	N92-10-P	Perimeter area	0.005	28	2148
O	05/20/92	O92-11-A	Previously abated area	0.005	28	2139
O	05/20/92	O92-12-A	Previously abated area	0.002	14	2188
O	05/20/92	O92-13-A	Previously abated area	0.002	14	2167
O	05/20/92	O92-14-A	Previously abated area	0	0	2186
O	05/20/92	O92-15-A	Previously abated area	0	0	2179
O	05/20/92	O92-01-O	Outdoors	0.038	206	2066
O	05/20/92	O92-02-O	Outdoors	0.047	254	2087
O	05/20/92	O92-03-O	Outdoors	0.024	127	2066
O	05/20/92	O92-04-O	Outdoors	0.015	79	2045
O	05/20/92	O92-05-O	Outdoors	0.012	64	2066
O	05/20/92	O92-06-P	Perimeter area	0	0	2108
O	05/20/92	O92-07-P	Perimeter area	0	0	2217

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	s/mm²	Air Volume, L
O	05/20/92	O92-08-P	Perimeter area	0.002	14	2181
O	05/20/92	O92-09-P	Perimeter area	0.003	14	2066
O	05/20/92	O92-10-P	Perimeter area	0	0	2237
P	05/21/92	P92-11-A	Previously abated area	0.010	56	2155
P	05/21/92	P92-12-A	Previously abated area	0	0	2241
P	05/21/92	P92-13-A	Previously abated area	0.002	14	2192
P	05/21/92	P92-14-A	Previously abated area	0.002	14	2188
P	05/21/92	P92-15-A	Previously abated area	0	0	2164
P	05/21/92	P92-01-O	Outdoors	0.010	56	2091
P	05/21/92	P92-02-O	Outdoors	0.009	48	2091
P	05/21/92	P92-03-O	Outdoors	0	0	2118
P	05/21/92	P92-04-O	Outdoors	0.018	95	2091
P	05/21/92	P92-06-P	Perimeter area	0	0	2164
P	05/21/92	P92-07-P	Perimeter area	0.020	111	2149
P	05/21/92	P92-08-P	Perimeter area	0	0	2152
P	05/21/92	P92-08-PR	Replicate analysis of P92-08-P	0	0	2152
P	05/21/92	P92-09-P	Perimeter area	0	0	2209
P	05/21/92	P92-10-P	Perimeter area	0.010	56	2051
Q	05/14/92	Q92-11-A	Previously abated area	0.025	111	1744
Q	05/14/92	Q92-12-A	Previously abated area	0.035	181	2004
Q	05/14/92	Q92-13-A	Previously abated area	0.070	361	1973
Q	05/14/92	Q92-14-A	Previously abated area	0.104	528	1949
Q	05/14/92	Q92-14-AD	Duplicate analysis of Q92-14-A	0.099	500	1949
Q	05/14/92	Q92-15-A	Previously abated area	0.033	167	1943
Q	05/14/92	Q92-15-AR	Replicate analysis of Q92-15-A	0.044	222	1943
Q	05/14/92	Q92-16-OB	Open field blank	-	0	0
Q	08/24/92	Q892-11A	Previously abated area	0	0	1259
Q	08/24/92	Q892-12A	Previously abated area	0.020	69	1345
Q	08/24/92	Q892-13A	Previously abated area	0.011	42	1528
Q	08/24/92	Q892-14A	Previously abated area	0.012	48	1589
Q	08/24/92	Q892-15A	Previously abated area	0.003	14	161
R	05/19/92	R92-11-A	Previously abated area	0.005	28	2089
R	05/19/92	R92-11-AR	Replicate analysis of R92-11-A	0.003	14	2089
R	05/19/92	R92-12-A	Previously abated area	0	0	1882
R	05/19/92	R92-13-A	Previously abated area	0	0	1967
R	05/19/92	R92-14-A	Previously abated area	0	0	1967
R	05/19/92	R92-15-A	Previously abated area	0	0	1944
R	05/19/92	R92-01-O	Outdoors	0.003	16	2077
R	05/19/92	R92-02-O	Outdoors	0	0	2058
R	05/19/92	R92-03-O	Outdoors	0.006	32	2019
R	05/19/92	R92-04-O	Outdoors	0.006	32	2038
R	05/19/92	R92-05-O	Outdoors	0.003	16	2127
R	05/19/92	R92-16-OB	Open field blank	-	0	0
R	05/19/92	R92-17-OB	Open field blank	-	0	0
R	05/19/92	R92-18-CB	Closed field blank	-	0	0

(continued)

APPENDIX A (continued)

Site	Date Sampled	Sample Number	Sample Location	Concentration s/cm³	s/mm²	Air Volume, L
R	05/19/92	R92-06-P	Perimeter area	0	0	2053
R	05/19/92	R92-07-P	Perimeter area	0.008	42	1955
R	05/19/92	R92-08-P	Perimeter area	0	0	1967
R	05/19/92	R92-09-P	Perimeter area	0.006	28	1770
R	05/19/92	R92-10-P	Perimeter area	0.003	14	1728
R	05/19/92	R92-10-PD	Duplicate analysis of R92-10-P	0.003	14	1728
S	05/19/92	S92-11-A	Previously abated area	0	0	2196
S	05/19/92	S92-12-A	Previously abated area	0	0	2133
S	05/19/92	S92-13-A	Previously abated area	0	0	2181
S	05/19/92	S92-14-A	Previously abated area	0	0	2134
S	05/19/92	S92-15-A	Previously abated area	0	0	2217
S	05/19/92	S92-02-O	Outdoors	0	0	2164
S	05/19/92	S92-03-O	Outdoors	0.006	32	2121
S	05/19/92	S92-04-O	Outdoors	0.003	16	2164
S	05/19/92	S92-05-O	Outdoors	0.020	111	2121
S	05/19/92	S92-16-OB	Open field blank	-	0	0
S	05/19/92	S92-17-OB	Open field blank	-	0	0
S	05/19/92	S92-18-CB	Closed field blank	-	0	0
S	05/19/92	S92-06-P	Perimeter area	0	0	2155
S	05/19/92	S92-07-P	Perimeter area	0.002	14	2155
S	05/19/92	S92-08-P	Perimeter area	0.002	14	2205
S	05/19/92	S92-09-P	Perimeter area	0.002	14	2189
S	05/19/92	S92-10-P	Perimeter area	0	0	2164
T	05/18/92	T92-11-A	Previously abated area	0	0	2057
T	05/18/92	T92-12-A	Previously abated area	0	0	2031
T	05/18/92	T92-13-A	Previously abated area	0	0	2011
T	05/18/92	T92-14-A	Previously abated area	0	0	2025
T	05/18/92	T92-15-A	Previously abated area	0	0	1991
T	05/18/92	T92-15-AR	Replicate analysis of T92-15-A	0	0	1991
T	05/18/92	T92-01-O	Outdoors	0.003	16	2012
T	05/18/92	T92-02-O	Outdoors	0	0	2012
T	05/18/92	T92-03-O	Outdoors	0.003	16	1987
T	05/18/92	T92-04-O	Outdoors	0	0	2006
T	05/18/92	T92-05-O	Outdoors	0	0	1967
T	05/18/92	T92-16-OB	Open field blank	-	0	0
T	05/18/92	T92-17-OB	Open field blank	-	0	0
T	05/18/92	T92-18-CB	Closed field blank	-	0	0
T	05/18/92	T92-06-P	Perimeter area	0	0	2043
T	05/18/92	T92-07-P	Perimeter area	0	0	2050
T	05/18/92	T92-07-PD	Duplicate analysis of T92-07-P	0	0	2050
T	05/18/92	T92-08-P	Perimeter area	0	0	2068
T	05/18/92	T92-09-P	Perimeter area	0.003	14	2054
T	05/18/92	T92-10-P	Perimeter area	0	0	2074

APPENDIX B

CASE HISTORIES

SITE A

Background

Site Description

The abatement project at this single-story school building involved the removal of approximately 19,100 ft^2 of spray-applied asbestos-containing ceiling plaster. The abatement area included corridors, classrooms, offices, and recreational rooms. The project specifications indicated that the asbestos content of the ceiling plaster was approximately 5 to 10 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside of the abatement area but inside the building), and outdoors at approximately the same time and location as the samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during actual occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-1 summarizes the results of the four sampling efforts. Figure B-1 illustrates the mean airborne asbestos concentrations at Site A. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-2. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (22 s/mm^2) was

TABLE B-1. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE A[a]

Sampling Period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.002	0	0.006	0.001	0	0.003	0	0	0
Simulated occupancy-1990	0.007	0	0.028	0.011	0	0.038	0	0	0
Occupied conditions-1991	0.001	0	0.003	0.003	0	0.008	0.003	0	0.005
Occupied conditions-1992	0.001	0	0.002	0.001	0	0.002	0.008	0	0.017

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-2. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE A

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0936	A(0.002) P(0.001) O(0)
Simulated occupancy-1990	0.3160	P(0.011) A(0.007) O(0)
Occupied conditions-1991	0.1665	P(0.003) O(0.003) A(0.001)
Occupied conditions-1992	0.0186	O(0.008) P(0.001) A(0.001)

[a] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

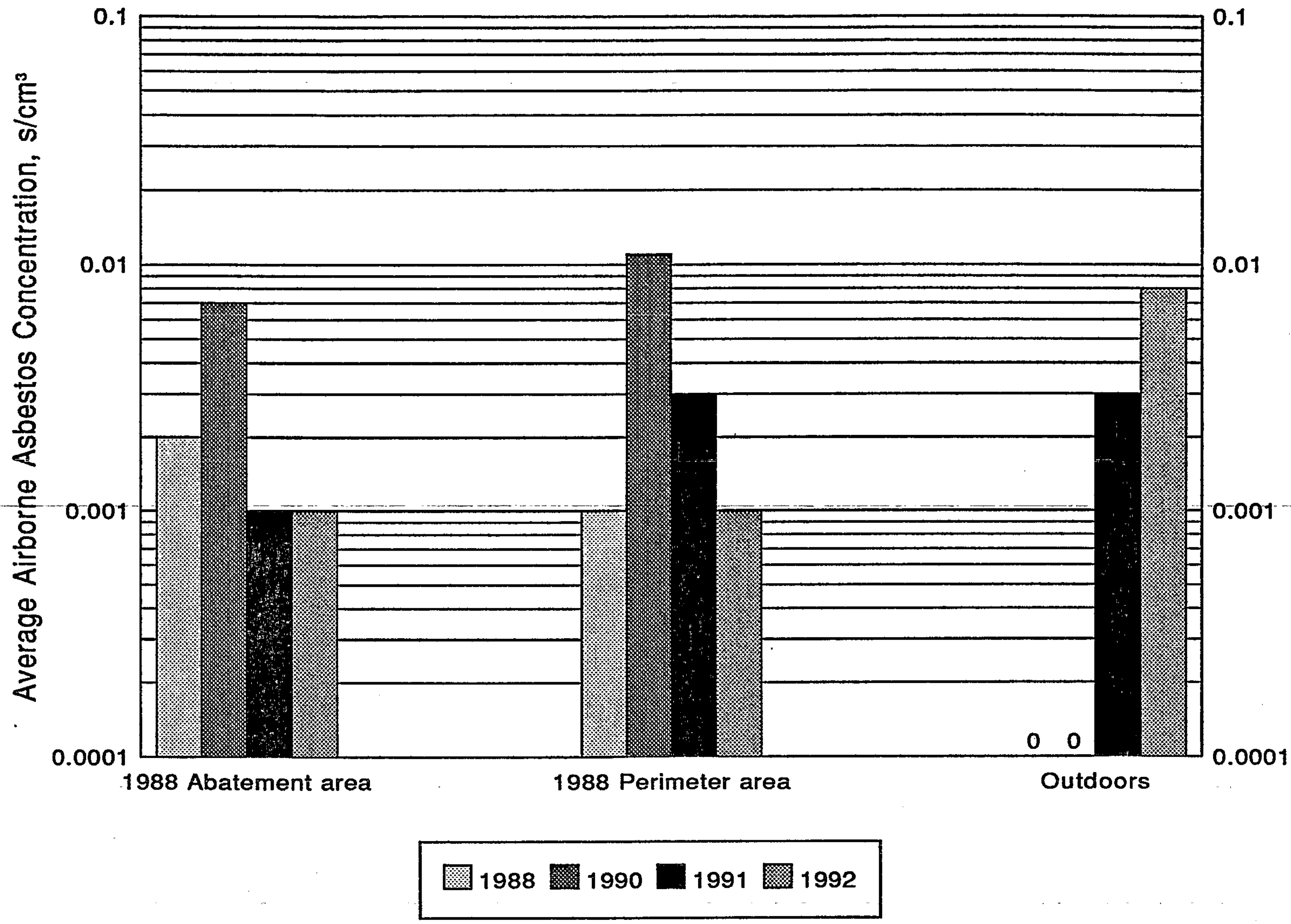

Figure B-1. Average airborne asbestos concentrations measured at Site A.

below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test irregardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.001 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.011 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.011 s/cm^3).

Occupied Conditions - 1991

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.003 s/cm^3).

Occupied Conditions - 1992

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.008 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.008 s/cm^3).

Comparison of Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. The result of the ANOVA analysis, along with the results of the Tukey multiple comparison test, are presented in Table B-3. The following subsections summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-3. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE A

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.5855	1990(0.0007) 1988(0.002) 1991(0.001) 1992(0.001)
Perimeter area	0.2881	1990(0.011) 1991(0.003) 1988(0.001) 1992(0.001)
Outdoors	0.0015	1992(0.008) 1991(0.003) 1990(0) 1988(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not statistically significantly different.

1988 Abatement Area

Differences in average airborne asbestos concentrations measured in the abatement area were not statistically significant. The highest average concentration (0.007 s/cm^3) and the highest individual concentration (0.028 s/cm^3) were measured 2 years after the 1988 abatement.

Perimeter Area

Differences in average airborne asbestos concentrations measured in the perimeter area were not statistically significant. The highest average concentration (0.011 s/cm^3) and the highest individual concentration (0.038 s/cm^3) were measured 2 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentration measured in 1992 (0.008 s/cm^3) was significantly higher than the average concentrations measured in 1988 (0 s/cm^3) and 1990 (0 s/cm^3). Average outdoor levels measured in 1991 and 1992 were not significantly different. The highest individual outdoor concentration (0.017 s/cm^3) was measured in 1992.

Structure Morphology and Size Distributions

Table B-4 presents the distribution of structure type and morphology at each sampling location for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 55 asbestos structures, of which 98.2 percent were chrysotile asbestos and 1.8 percent were amphibole. Overall, the asbestos structures were primarily fibers (74.5 percent), and to a lesser extent, matrices (16.4 percent), clusters (5.5 percent), and bundles (3.6 percent).

Table B-5 presents the cumulative size distribution of asbestos samples at each sampling location for each year of monitoring. Overall, 94.5 percent of the observed asbestos structures were less than 5 µm in length. Of the 41 asbestos fibers observed, only 1 fiber (2.4 percent) was greater than 5 µm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site A as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Four visual inspections were required at this site. The site failed the first two because live electrical outlets were present inside the containment and asbestos-contaminated water was present in the toilets of the men's restroom and in the sink in the janitor's closet. Workers were observed dumping the contaminated mop water into drains, toilets, and sinks. The site failed the third visual inspection because of debris found on several skylights, on horizontal surfaces, in wall penetrations, and at the top of wooden and concrete walls. Pipe wrap was also left on pipes. The contractor was again required to reclean these areas. When the areas were recleaned, NJDOH conducted a fourth visual inspection and the site passed.

TABLE B-4. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE A

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure Morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	4	100	0	25.0	25.0	0	50.0
	1990	7	100	0	57.1	0	28.6	14.3
	1991	1	100	0	100	0	0	0
	1992	3	100	0	66.7	0	0	33.3
Perimeter area	1988	1	100	0	100	0	0	0
	1990	12	100	0	83.3	0	8.3	8.3
	1991	6	83.3	16.7	100	0	0	0
	1992	1	100	0	0	0	0	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	6	100	0	100	0	0	0
	1992	14	100	0	71.4	7.1	0	21.4

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-5. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE A

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	4	50.0	100	100	100	100	100
	1990	7	28.6	57.1	85.7	100	100	100
	1991	1	100	100	100	100	100	100
	1992	3	33.3	66.7	66.7	66.7	66.7	100
Perimeter area	1988	1	100	100	100	100	100	100
	1990	12	25.0	58.3	75.0	75.0	83.3	91.7
	1991	6	66.7	100	100	100	100	100
	1992	1	100	100	100	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	6	100	100	100	100	100	100
	1992	14	85.7	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

1991 Inspection

Although monitoring conducted in May 1991 indicated airborne asbestos levels were within the AHERA criterion, NJDOH conducted another visual inspection at Site A on November 7, 1991, as a followup to the 1988 visual inspection. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). In November 1991, the NJDOH inspector examined only those areas indicated in the following subsections

1988 Abatement Areas

Corridors--Debris (4 to 6 percent chrysotile) from the thermal system insulation was present on the upper surface of the suspended ceiling system (Table B-6). Corrugated pipe insulation (21 percent chrysotile) penetrated concrete-masonry walls at the radiators and other water-service locations (Table B-6). These materials were not included in the Asbestos Management Plan.

Library--Damaged corrugated pipe insulation (37 percent chrysotile) was noted in the Nesbitt heat exchanger units (Table B-6). These materials do not appear in the Asbestos Management Plan.

Student Common Area--Debris from damaged thermal system insulation was noted in the vents above the telephone booth.

1988 Perimeter Areas

Music Room--Corrugated pipe insulation penetrated the concrete-masonry walls of the music room and other adjoining rooms from the corridors. These materials were not included in the Asbestos Management Plan.

Office and Other Areas--Offices and various other areas are served by the Nesbitt heat exchanger units. The associated piping is insulated with corrugated insulation. These materials were not included in the Asbestos Management Plan.

Conclusions

Asbestos-containing thermal system insulation was present in several areas that were not noted in the Asbestos Management Plan. Asbestos-containing debris was present on the upper surface of the suspended ceiling system in the corridors. Disturbance of these materials during renovation or O&M activities could result in the release of asbestos structures.

TABLE B-6. SUMMARY OF BULK SAMPLE RESULTS - SITE A 1991 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Area		
Hall by radio room	Joint residue in pipe hanger	6% chrysotile asbestos
Hall at faculty room	Corrugated pipe insulation at radiator	21% chrysotile asbestos Trace crocidolite asbestos
Hall between faculty and radio rooms	Pipe joint material	4% chrysotile asbestos
Library	Corrugated pipe insulation at radiator	37% chrysotile asbestos
Library	Felt motor pad, radiator	Negative

SITE B

Background

Site Description

During the summer of 1988, two asbestos abatement projects were conducted at this school (Sites B and Q). Spray-applied acoustical ceiling plaster was removed from the second floor (Site B) and from the first floor (Site Q). The abatement area for both sites included corridors, classrooms, and offices. The ceiling plaster contained approximately 2 to 6 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this school. There has been no additional abatement activity since 1988.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside of the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST.

In 1990, air samples were collected at this school by a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988.

In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-7 summarizes the air monitoring results from 1988, 1990, 1991, and 1992. Figure B-2 illustrates the mean airborne asbestos concentrations at Site B. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-8. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-7. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE B[a]

Sampling period	Abatement area (N=5)			Perimeter Area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0.001	0	0.004	0	0	0
Postabatement-1988	0.016	0.004	0.030	0.008	0	0.023	0.001	0	0.004
Simulated occupancy-1990	0.015	0.005	0.022	0.010	0	0.040	0.001	0	0.005
Occupied conditions-1991	0.027	0.010	0.055	0.012	0.004	0.024	0.001	0	0.004
Occupied conditions-1992	0.044	0.014	0.102	0.438	0.142	1.02	0.001	0	0.003

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-8. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE B

Sampling Period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.3466	P(0.001) O(0)
Postabatement-1988	0.0128	A(0.016) P(0.008) O(0.001)
Simulated occupancy-1990	0.0299	A(0.015) P(0.010) O(0.001)
Occupied conditions-1991	0.0002	A(0.027) P(0.012) O(0.001)
Occupied conditions-1992	0.0001	P(0.438) A(0.044) O(0.001)

[a] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

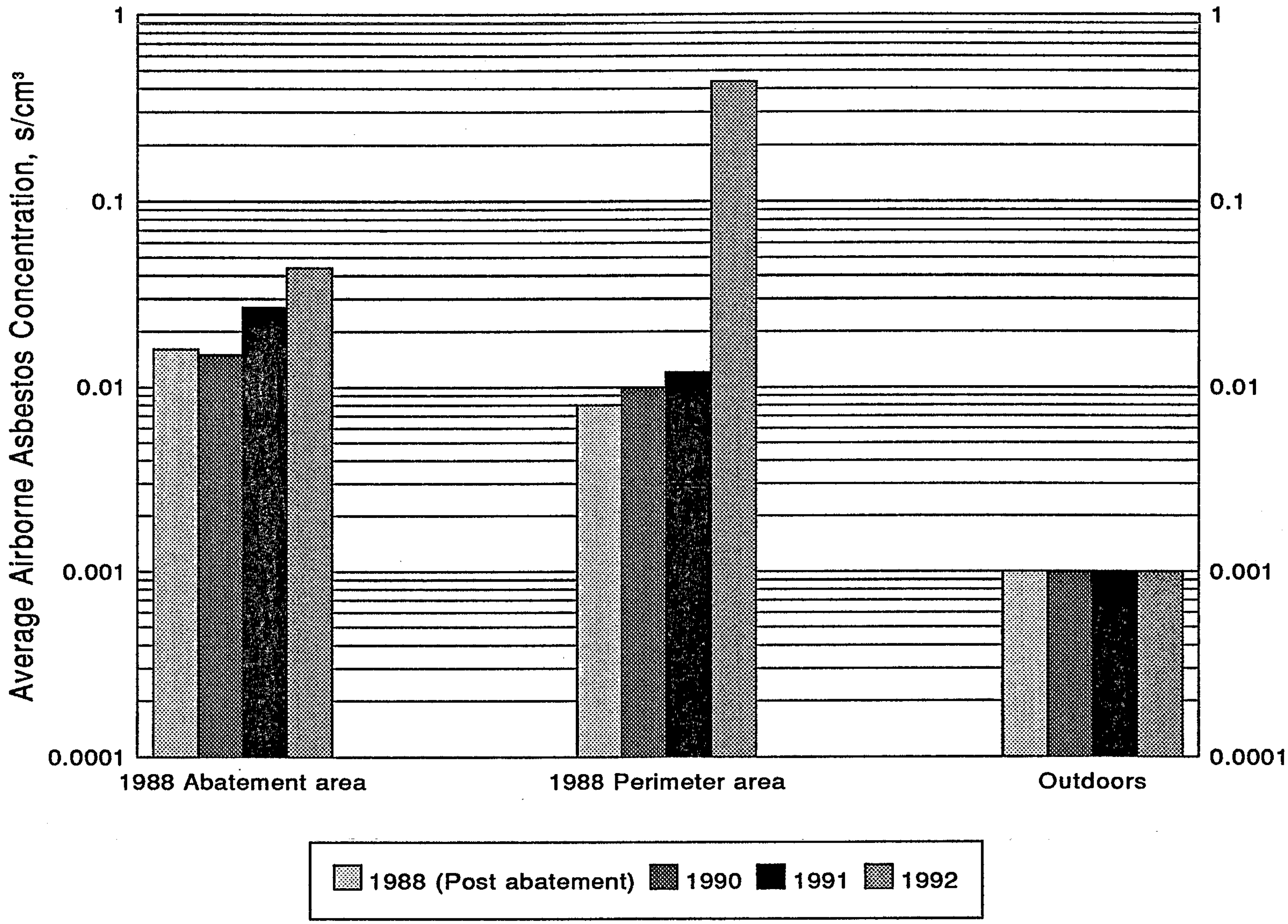

Figure B-2. Average airborne asbestos concentrations measured at Site B.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (109 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test if the abatement area concentrations were compared with the outdoor concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.016 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3). This result is consistent with the AHERA Z-test comparison reported previously.

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.008 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.016 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.008 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the previously abated area 2 years after the 1988 abatement (0.015 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.010 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.015 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter areas (0.010 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.027 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.012 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.027 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter areas (0.012 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.044 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.438 s/cm^3) was significantly greater than the average outdoor concentration of airborne asbestos (0.001 s/cm^3). The unusually high average level in the perimeter areas is due primarily to one sample (1.02 s/cm^3). The other four samples ranged from 0.014 to 0.038 s/cm^3.

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.044 s/cm^3) was significantly less than the average airborne asbestos concentration measured in the perimeter areas (0.438 s/cm^3). The unusually high average level in the perimeter areas is due primarily to one sample (1.02 s/cm^3). The other four samples ranged from 0.014 to 0.038 s/cm^3.

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. The result of the ANOVA analysis is presented in Table B-9 along with the results of the Tukey multiple comparison test. The following subsections summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

Although average airborne asbestos concentrations measured in the abatement area appeared to increase consistently in 1991 and 1992, the differences in the average levels were not statistically significant. The highest average concentration (0.044 s/cm^3) and the highest individual concentration (0.102 s/cm^3) were measured 4 years after the 1988 abatement.

Perimeter Area

The average airborne asbestos concentrations measured in the perimeter area 4 years after the 1988 abatement (0.438 s/cm^3) was significantly higher than the average levels measured in 1988 (pre and postabatement), 1990, and 1991. The differences between the average levels in 1988, 1990, and 1991 were not statistically significant. The highest average concentration (0.438 s/cm^3) and the highest individual concentration (1.02 s/cm^3) were measured 4 years after the 1988 abatement.

Outdoors

Differences in average airborne asbestos concentrations measured outdoors in each of the 4 years were not statistically significant. The highest individual concentration (0.005 s/cm^3) was measured in 1990, 2 years after abatement.

TABLE B-9. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE B

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.1128	1992(0.044) 1991(0.027) 1988(0.016) 1990(0.015)
Perimeter area	0.0001	1992(0.438) 1991(0.012) 1990(0.010) 1988(0.008) 1988P(0.001)
Outdoors	0.8990	1988(0.001) 1990(0.001) 1991(0.001) 1992(0.001) 1988P(O)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = postabatement.

Structure Morphology and Size Distributions

Table B-10 presents the distribution of structure type and morphology at each sampling location for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 716 asbestos structures, of which 99.3 percent were chrysotile asbestos and 0.7 percent were amphibole. Overall, the asbestos structures were primarily fibers (97.8 percent), and to a lesser extent, bundles (1.4 percent), matrices (0.7 percent), and clusters (0.1 percent).

Table B-11 presents the cumulative size distribution of asbestos samples at each sampling location for each year of monitoring. Overall, 99.2 percent of the observed asbestos structures were less than 5 µm in length. Of the 700 asbestos fibers observed, only 5 fibers (0.7 percent) were greater than 5 µm in length.

Followup Air Monitoring - August 1991

Because the average airborne asbestos concentration in May 1991 (0.027 s/cm^3) exceeded 0.02 s/cm^3 in the previously abated area, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 13, 1991, to determine whether airborne asbestos was still present at levels similar to those measured in May 1991. The August 13 results revealed an average airborne asbestos concentration in the previously abated area of less than 0.02 s/cm^3 (0.018 s/cm^3); therefore, no further monitoring activity was required at this school. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

Followup Air Monitoring - August 1992

Because the average airborne asbestos concentration in the previously abated area (0.044 s/cm^3) and in the perimeter area (0.438 s/cm^3) exceeded 0.02 s/cm^3, EPA/NJDOH conducted followup monitoring in July 1992 under simulated occupancy conditions to determine whether airborne asbestos concentrations were still present at the levels observed in May 1992. The average airborne asbestos concentration measured in the perimeter area in July (0.006 s/cm^3) was below 0.02 s/cm^3; therefore, no further action was required in this area. The NJDOH did, however, require a response action in the previously abated area at this school based on the May 1992 data. The school subsequently employed a licensed asbestos-abatement contractor to clean the previously abated area. When the cleaning action was complete, NJDOH conducted followup air monitoring in August 1992 to determine the residual levels of airborne asbestos. The average airborne asbestos concentration measured in August 1992 (0.007 s/cm^3) was below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school.

TABLE B-10. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE B

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	21	100	0	100	0	0	0
	1990	14	64.3	35.7	92.9	0	0	0
	1991	40	100	0	97.5	0	0	2.5
	1992	81	100	0	92.6	4.9	0	2.5
Perimeter area	1988	11	100	0	90.9	9.1	0	0
	1990	10	100	0	100	0	0	0
	1991	17	100	0	88.2	0	0	11.8
	1992	518	100	0	99.2	0.8	0	0
Outdoors	1988	1	100	0	0	0	100	0
	1990	1	100	0	100	0	0	0
	1991	1	100	0	100	0	0	0
	1992	1	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-11. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE B

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 μm	≤2 μm	≤3 μm	≤4 μm	≤5 μm	≤10 μm
Abatement area	1988	21	61.9	95.2	95.2	100	100	100
	1990	14	35.7	57.1	57.1	57.1	57.1	78.6
	1991	40	80	100	100	100	100	100
	1992	81	82.7	98.8	100	100	100	100
Perimeter area	1988	11	27.3	72.7	100	100	100	100
	1990	10	60	90	100	100	100	100
	1991	17	70.6	100	100	100	100	100
	1992	518	77.8	99.6	99.8	100	100	100
Outdoors	1988	1	0	0	100	100	100	100
	1990	1	100	100	100	100	100	100
	1991	1	0	100	100	100	100	100
	1992	1	0	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site B as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Three visual inspections were required at this site. The site failed the first visual inspection because of the presence of gross debris on the tops of closets, in the corner window sills, at floor-wall and ceiling-wall junctions, in cracks and crevices, on ceiling rafters and beams, on floors, and on auxiliary equipment. The contractor was required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection. The site failed this visual inspection because of debris on clocks, windows, ceiling beams, tops of blackboards, and horizontal surfaces in the classrooms and closets. The contractor was again required to reclean the affected areas. When the areas were recleaned, NJDOH conducted a third visual inspection. The site passed the third visual inspection with the stipulation that overhead areas would be sprayed with an encapsulant.

Background for 1991 and 1992 Inspections

On August 14, 1991, and July 16, 1992, NJDOH conducted a visual inspection at Sites B and Q to determine potential sources of airborne asbestos measured by EPA and NJDOH in May 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in August 1991 and July 1992.

1991 Inspection

1988 Abatement Areas

Second Floor Classrooms--Two samples of overspray and debris were obtained from the structural steel and closet overhead areas (Table B-12). These samples tested positive for chrysotile asbestos. All areas examined showed signs of inadequate encapsulation.

1988 Perimeter Areas

In the basement all-purpose room, thermal system insulation (TSI) not identified in the Asbestos Management Plan was observed in the ceiling overhead spaces in the corridor, kitchen, and storage closet. This material appeared to be in generally good condition.

Conclusions

Incomplete assessment and abatement failed to account for overspray in the ceiling overhead spaces and the closet recessions. These asbestos-containing materials could have contributed to the elevated airborne asbestos levels measured in May 1991.

1992 Inspection

1988 Abatement Areas

In 1991, the NJDOH inspectors found residual spray-applied asbestos-containing material on the black iron trusses above the ceilings and ventilation panels in closets of the second floor classrooms. Samples of this material showed it to contain asbestos (Table B-12). The black iron trusses support the wire lathe, scratch coat, and acoustical plaster layers that make up the ceiling system in each classroom. The ceilings of the closets consist of wood paneling and a metal ventilation panel. It appeared that the flakes of asbestos-containing acoustical plaster on the trusses were the result of overspraying the scratch coat, which was done before the storage closets were installed. Overspray material was also observed on the trusses above the light fixtures, where holes for electrical connections or for mounting the fixtures were open during the spray application of the acoustical plaster.

The presence of oversprayed acoustical plaster on the trusses in the closets could not be verified during the July 16, 1992, visual inspection because the ceiling in the closets had been reinstalled and stored books and other materials in the closets made the ventilation panels inaccessible.

1988 Perimeter Area

Basement All-Purpose Room--In the soffit in the all-purpose room (which is accessible through access panels in the ceiling), some Aircell pipe insulation and cementitious elbows/fittings were noted. The fibrous-glass lines and cementitious fittings appeared to be in good condition; however, the Aircell insulation had opened (unsealed) seams and had delaminated in a couple of areas. These materials were not identified in the Asbestos Management Plan.

TABLE B-12. SUMMARY OF BULK SAMPLE RESULTS--SITE B 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
2nd floor classroom, closet overhead, truss	Flakes of spray-on debris	Positive[a], chrysotile asbestos
2nd floor classroom, top of closet	Flakes of spray-on debris	Positive, chrysotile asbestos
1988 Perimeter Areas		
Basement all-purpose room	Composite, ceiling sample	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples of which there is not adequate material available to allow a full quantitative evaluation, but are of sufficient size to determine that asbestos is present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Kitchen--Along the base of the exterior wall below the radiators inside the kitchen were extensive deposits of extremely friable, white, powdery material. These deposits are believed to have been caused by efflorescence of the concrete-masonry block and/or mortar. The white powdery material tested positive for asbestos (Table B-13). The flooring in the kitchen was 9 in. by 9 in. asbestos-containing (15 percent chrysotile) resilient floor tile (Table B-13). Two 15 in. by 15 in. transite hot plates were present on the grill. These materials were not identified in the Asbestos Management Plan.

Boiler Room--In the boiler room, the following asbestos-containing materials were noted (Table B-13): 1) mud used to seal the boiler segments; 2) a cementitious pipe elbow debris behind the hot water tank; 3) spray-on ceiling debris noted in the cavity of concrete-masonry wall at the make-up air feed for the boiler; 4) tan paint from the boiler stack. These materials were not identified in the Asbestos Management Plan.

Conclusions

A number of asbestos sources were identified that could have contributed to the elevated asbestos levels measured in 1992 (and 1991). Elevated levels in the classrooms and hallways could have been caused by disturbance of asbestos-containing dust and/or friable asbestos-containing acoustical plaster overspray on the steel trusses above the ceilings and vents in the classroom storage closets. Wind could cause air to flow from the roof vents through the ducts in this passive ventilation system and into the classrooms and hallways.

The elevated asbestos levels in the kitchen could be due to the extensive deposits of extremely friable, white, powdery material caused by efflorescence of the concrete-masonry block and/or mortar. Other possible contributory sources are the transite plates and asbestos-containing resilient floor tile.

TABLE B-13. SUMMARY OF BULK SAMPLE RESULTS - SITE B 1992 INSPECTION

Location	Type of Material	Analyses
1988 Perimeter Areas		
Kitchen, floor at south wall	White powder	Positive[a], chrysotile asbestos
Kitchen, wood sink	White cement spray	Positive, chrysotile asbestos
Kitchen, south wall	Blue paint/white undercoat	Positive chrysotile asbestos
Kitchen, south wall on floor	White efflorescence	Positive, chrysotile asbestos
Kitchen, south wall surface	White efflorescence	Positive, chrysotile, asbestos
Kitchen, south wall	Mortar, gray cement	Negative
Kitchen, south wall	Concrete-masonry block	2% chrysotile asbestos
Kitchen by storage room	Vinyl floor tile, grey 9" x 9"	15% chrysotile asbestos
Kitchen by storage room	Mortar from floor trap	Negative
Bingo hall	Floor paint, grey	Negative
Bingo hall, east wall	Glue paint with yellow and green	1% chrysotile asbestos
Bingo hall, NE corner	Concrete-masonry block	Negative
Bingo hall, girls' room	Paint	Negative
Bingo hall, girls' room	Soft debris in floor drain	Negative
Boiler room	Boiler segment mud	30% chrysotile asbestos
Boiler room	Boiler, fiber, rock wood	Negative
Boiler room, beam	Plaster/granular cement	Negative
Boiler room, ceiling pipe entry	Overspray, soft granular	Trace[b], chrysotile asbestos
Boiler room, air entry	Spray on debris	2% chrysotile asbestos
Boiler room, chimney	Paint, tan	Positive, chrysotile asbestos
Boiler room, beam	Paint and plaster	Trace, chrysotile asbestos
Boiler room, floor	Elbow debris, hot water heater	2% chrysotile asbestos
Boiler room	Mortar debris on pipe	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples of which there is not adequate material available to show a full quantitative evaluation, but are of sufficient size to determine that asbestos is present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

[b] Trace = <1 percent asbestos.

SITE C

Background

Site Description

During the summer of 1988, two asbestos abatement projects were conducted at this school (Sites C and M). Asbestos-containing thermal system insulation (TSI) was removed from a boiler, water tank, fan duct, and pipes in the boiler room located in the basement and from pipes in the corridor adjacent to the boiler room (Site C), and from pipes in the corridors, classrooms, offices, storage rooms, and gymnasium located in the basement (Site M). The TSI contained approximately 40 to 60 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. No additional abatement activity has taken place since 1988.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside of the abatement area, but inside the building) and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-14 summarizes the results from the five sampling efforts. Figure B-3 illustrates the mean airborne asbestos concentrations at Site C. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-15. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-14. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE C[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0.001	0	0.004	0.003	0	0.011
Postabatement-1988	0.060	0.004	0.146	0.002	0	0.008	0.004	0	0.016
Simulated occupancy-1990	0.001	0	0.005	0.001	0	0.005	0	0	0
Occupied conditions-1991	0.005	0	0.012	0.001	0	0.003	0.003	0	0.007
Occupied conditions-1992	0.008	0	0.021	0.003	0	0.005	0.003	0	0.007

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-15. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE C

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.4466	O(0.003) P(0.001)
Postabatement-1988	0.0057	A(0.060) O(0.004) P(0.002)
Simulated occupancy-1990	0.6186	A(0.001) P(0.001) O(0)
Occupied conditions-1991	0.2823	A(0.005) O(0.003) P(0.001)
Occupied conditions-1992	0.5566	A(0.008) P(0.003) O(0.003)

[a] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

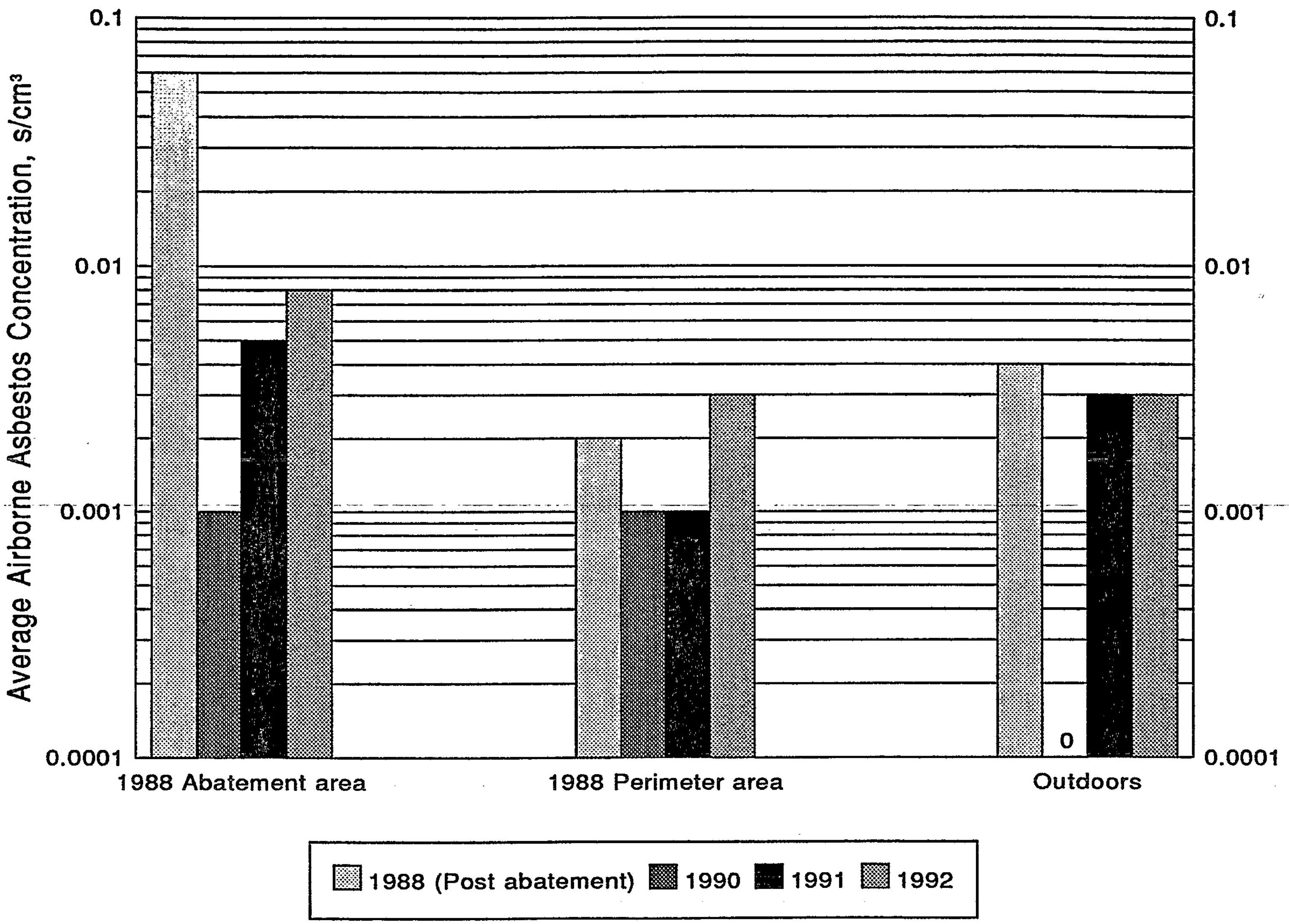

Figure B-3. Average airborne asbestos concentrations measured at Site C.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (397 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test irregardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by the use of the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.060 s/cm^3) was significantly greater than the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different than the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.060 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.002 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.001 s/cm^3) was significantly greater than the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter areas (0.001 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.008 s/cm^3) was not significantly different from the average concentration measured (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average outdoor concentration of airborne asbestos (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.008 s/cm^3) was significantly less than the average airborne asbestos concentration measured in the perimeter areas (0.003 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-16 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The following subsections summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

Although average airborne asbestos concentrations measured in the abatement area appeared to increase consistently in 1991 and 1992, the differences in the average levels were not statistically significant. The highest average concentration (0.060 s/cm^3) and the highest individual concentration (0.146 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter Area

The differences between the average levels in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.003 s/cm^3) was measured 4 years after the 1988 abatement. The highest individual concentration (0.008 s/cm^3) was measured during the AHERA clearance phase of the 1988 abatement.

TABLE B-16. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE C

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0079	1988(0.060) 1992(0.044) 1991(0.005) 1990(0.001)
Perimeter area	0.3255	1992(0.003) 1988(0.002) 1990(0.001) 1991(0.001) 1988P(0.001)
Outdoors	0.5835	1988(0.004) 1991(0.003) 1992(0.003) 1988 P(0.003) 1990(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement.

Outdoors

Differences in average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.004 s/cm^3) and the highest individual concentration (0.016 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-17 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 126 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (67.5 percent), and to a lesser extent, matrices (21.4 percent), bundles (5.6 percent), and clusters (5.6 percent).

TABLE B-17. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE C

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	77	100	0	53.2	7.8	9.1	29.9
	1990	1	100	0	0	0	0	100
	1991	8	100	0	75	12.5	0	12.5
	1992	15	100	0	100	0	0	0
Perimeter area	1988	2	100	0	100	0	0	0
	1990	1	100	0	100	0	0	0
	1991	1	100	0	100	0	0	0
	1992	6	100	0	100	0	0	0
Outdoors	1988	5	100	0	80.0	0	0	20.0
	1990	0	-	-	-		-	-
	1991	6	100	0	83.3	0	0	16.7
	1992	4	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Table B-18 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 83.3 percent of the observed asbestos structures were less than 5 µm in length. Of these 85 asbestos fibers, 13 (15.3 percent) were greater than 5 µm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site C as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

One visual inspection was required at this site. Some minor debris was found on pipe elbows and joints and on some horizontal surfaces. These elbows, joints, and horizontal surfaces were cleaned while the inspector was in the containment area, and the site subsequently passed the first visual inspection.

1991 Inspection

Although monitoring conducted in May 1991 found airborne asbestos levels within the AHERA criterion, on August 14, 1991, NJDOH conducted a visual inspection at Sites C and M as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in August 1991.

1988 Abatement Areas

Miscellaneous debris mixed in with the coal from the boiler room tested positive for chrysotile (19 percent), amosite (3 percent), and crocidolite (trace) asbestos (Table B-19). The TSI debris mixed in with the coal tested positive for chrysotile asbestos. The TSI debris found under the boiler room stairway tested positive for asbestos (67 percent chrysotile).

1988 Perimeter Area

Large Gymnasium--Plaster dust and debris from renovation work were widespread along the north wall. No samples of the plaster dust were collected.

TABLE B-18. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE C

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	77	6.5	35.1	57.1	67.5	72.7	94.8
	1990	1	0	100	100	100	100	100
	1991	8	50	100	100	100	100	100
	1992	15	60.0	93.3	100	100	100	100
Perimeter area	1988	2	50.0	100	100	100	100	100
	1990	1	100	100	100	100	100	100
	1991	1	0	0	0	0	100	100
	1992	6	83.3	100	100	100	100	100
Outdoors	1988	5	20.0	40.0	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	6	66.7	100	100	100	100	100
	1992	4	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-19. SUMMARY OF BULK SAMPLE RESULTS--SITE C 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
Boiler room, coal area	Debris mixed in coal	3% chrysotile, 19% amosite, positive, crocidolite asbestos
Boiler room, coal area	TSI debris	Positive, chrysotile asbestos
Boiler room, under stairs	TSI debris	67% chrysotile asbestos
1988 Perimeter Area		
Basement recreation room/classroom	Plaster, top coat	Negative
Basement hallway	Plaster, top coat	Negative
Basement hallway	Plaster, browncoat	Positive[a], chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Classroom, Small Gymnasium, and Corridors--No TSI debris was found in these perimeter areas. Plaster debris from the wall and ceiling surfaces was evident in many areas. Top-coat plaster from the recreation room and hallway did not test positive for asbestos; however, the browncoat underlay in the adjoining hallway showed trace amounts of chrysotile asbestos (Table B-19). The storage and office areas were locked and could not be accessed.

Other Considerations

The school's Asbestos Management Plan identified plaster as an asbestos-containing building material (ACBM). Samples taken by the NJDOH were reported as either <1 percent chrysotile asbestos or as negative for asbestos (Table B-19).

Although none of these materials tested greater than 1 percent asbestos, the Asbestos Management Plan classified them as friable surfacing materials with damage and indicated that repairs would be made by September 1, 1989. At the time of the NJDOH inspection, no repairs had been made, however, the plaster debris on the floor surfaces in the large gymnasium had been cleaned up.

Conclusions

The deterioration of the plaster in the building and activities involved in the renovation and repair of the plaster may have contributed to the elevated concentrations of airborne asbestos measured in May 1991.

SITE D

Background

Site Description

During the summer of 1988, this school underwent the removal of sprayed-on ceiling material and thermal system insulation (TSI) from the boiler room and adjoining mechanical spaces. The ceiling plaster was removed from the loading dock, book storage areas, boiler room, mechanical equipment room, and the electrical equipment room and its adjacent corridor. The TSI was removed from a water tank and pipes in the boiler room. The ceiling plaster and TSI contained approximately 20 to 35 percent chrysotile and 40 to 60 percent chrysotile asbestos, respectively. In 1990, 20 square feet of TSI was removed from a vertical conveyor shaft. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. No other asbestos-containing material has been abated since 1988.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-20 summarizes the results of the five sampling efforts. Figure B-4 illustrates the mean airborne asbestos concentrations at Site D. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-21. The following subsections following summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-20. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE D[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0	0	0	0	0	0
Postabatement- 1988	0.079	0.013	0.129	0.062	0.032	0.099	0.052	0.004	0.093
Simulated occupancy-1990	0.001	0	0.005	0.001	0	0.005	0	0	0
Occupied conditions-1991	0.020	0.003	0.059	0.004	0	0.009	0.014	0	0.012
Occupied conditions-1992	0.025	0	0.059	0.001	0	0.003	0.003	0	0.007

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-21. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE D

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	1.0	P(0) O(0)
Postabatement-1988	0.5619	A(0.070) P(0.062) O(0.052)
Simulated occupancy-1990	0.6186	A(0.001) P(0.001) O(0)
Occupied conditions-1991	0.0899	A(0.020) P(0.004) O(0.004)
Occupied conditions-1992	0.0099	A(0.025) P(0.001) O(0)

[a] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

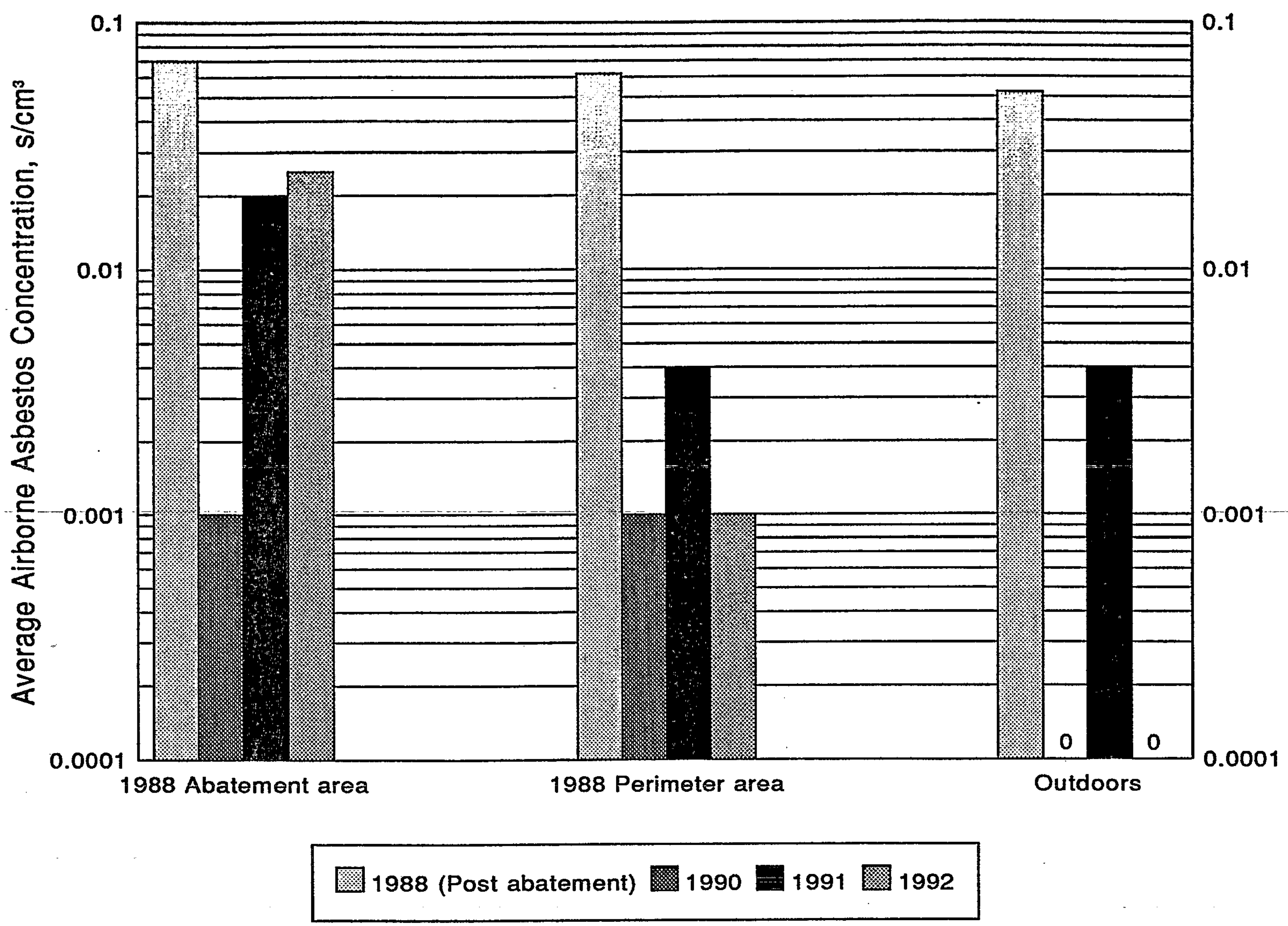

Figure B-4. Average airborne asbestos concentrations measured at Site D.

Summary of Air Monitoring Results

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (516 s/mm^2) exceeded 70 s/mm^2. The site would have passed the AHERA Z-test, however, regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results and would have passed the AHERA clearance test by using the EPA/NJDOH results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.0.079 s/cm^3) was not significantly different from the average concentration measured outdoors (0.052 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the 1988 abatement (0.062 s/cm^3) was not significantly different from the average concentration measured outdoors (0.052 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.079 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.062 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.020 s/cm^3) was not significantly different from the average concentration measured outdoors (0.014 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0.014 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.020 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.004 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.025 s/cm^3) was significantly greater than the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.025 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-22 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The following subsections summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

The average airborne asbestos concentration measured in the abatement area was significantly less in 1990 (0.003 s/cm^3) than in 1988 (0.065 s/cm^3). All other differences in average airborne asbestos concentrations measured in the abatement area were not statistically significant. The highest average concentration (0.065 s/cm^3) and the highest individual concentration (0.129 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter Area

The average postabatement airborne asbestos concentration measured in the perimeter area in 1988 was significantly greater than the average preabatement concentration measured in 1988, 1990, 1991, and 1992. The average concentration in 1991 was also significantly greater than the preabatement concentration measured in 1988. The highest average concentration (0.062 s/cm^3) and the highest individual concentration (0.099 s/cm³) were measured during the AHERA clearance phase of the 1988 abatement.

TABLE B-22. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE D

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0012	1988(0.070) 1992(0.025) 1991(0.020) 1990(0.001)
Perimeter area	0.0001	1988(0.062) 1991(0.004) 1990(0.001) 1992(0.001) 1988P(0)
Outdoors	0.0001	1988(0.052) 1991(0.004) 1990(0) 1992(0) 1988P(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm³) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement

Outdoors

The average airborne asbestos concentrations measured outdoors in 1990, 1991, and 1992 were not significantly different, but all were significantly less than the average concentration measured in 1988. The highest average concentration (0.052 s/cm³) and the highest individual concentration (0.093 s/cm³) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-23 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 samples collected in the perimeter area, and 20 samples collected outdoors yielded a total of 320 asbestos structures, of which 99.7 percent were chrysotile asbestos and 0.3 percent were amphibole. Overall, the asbestos structures were primarily fibers (83.4 percent), and to a lesser extent, matrices (12.2 percent), clusters (2.8 percent), and bundles (1.6 percent).

TABLE B-23. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE D

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	93	100	0	84.9	2.2	2.2	10.8
	1990	1	100	0	0	0	0	100
	1991	33	100	0	87.9	3.0	3.0	6.1
	1992	40	100	0	92.5	0	0	7.5
Perimeter area	1988	77	98.7	1.3	77.9	1.3	6.5	14.3
	1990	1	100	0	0	0	100	0
	1991	8	100	0	50.0	12.5	0	37.5
	1992	2	100	0	89.7	0	0	10.3
Outdoors	1988	58	100	0	89.7	0	0	10.3
	1990	0	-	-	-	-	-	-
	1991	7	100	0	57.1	0	0	42.9
	1992	0	-	-	-	-	-	--

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Table B-24 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 96.6 percent of the observed asbestos structures were less than 5 µm in length. Of the 267 asbestos fibers observed, only 4 (1.5 percent) were greater than 5 µm in length.

FollowUp Air Monitoring - August 1991

Because the April 1991 average airborne asbestos concentration in the previously abated area was 0.02 s/cm^3, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 13, 1991, to determine whether airborne asbestos was still present at levels similar to those measured in April. The August 13 results revealed an average airborne asbestos concentration in the previously abated area of less than 0.02 s/cm^3 (0.018 s/cm^3); therefore, no further monitoring activity was required at this site. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

FollowUp Air Monitoring - August 1992

Because the May 1992 average airborne asbestos concentration in the previously abated area (0.025 s/cm^3) exceeded 0.02 s/cm^3, NJDOH-EHS required response action at this school. The school subsequently used in-house staff to clean the previously abated and perimeter areas. When the cleaning action was complete, EPA/NJDOH conducted followup air monitoring in August 1992 to determine the residual levels of airborne asbestos. The average airborne asbestos concentrations in the previously abated area (0.008 s/cm^3) and perimeter area (0 s/cm^3) were both below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school.

NJDOH Visual Inspections

1988 Inspection

The NJDOH did not perform a visual inspection at this site. Upon completion of the final cleaning, the abatement contractor requested that a visual inspection be conducted by the onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification and did not identify any areas that required further cleaning.

1991 Inspection

On August 14, 1991, NJDOH conducted a visual Inspection at Site D to determine potential sources of airborne asbestos measured by EPA/NJDOH in April 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination

TABLE B-24. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE D

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	93	67.7	95.7	100	100	100	100
	1990	1	0	0	100	100	100	100
	1991	33	78.8	87.9	90.9	97.0	97.0	97.0
	1992	40	57.5	92.5	97.5	97.5	97.5	100
Perimeter area	1988	77	62.3	84.4	89.6	90.9	92.2	98.7
	1990	1	0	100	100	100	100	100
	1991	8	62.5	75.0	75.0	100	100	100
	1992	2	50	100	100	100	100	100
Outdoors	1988	58	74.1	96.6	98.3	98.3	98.3	100
	1990	0	-	-	-	-	-	-
	1991	7	14.3	42.9	57.1	57.1	71.4	100
	1992	0	-	-	-	-	-	-

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

(i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined.

1988 Abatement Area

Electrical Room--Ceiling debris (17 percent chrysotile asbestos) was present on the top of ductwork, electrical boxes, and wiring and in wall penetrations (Table B-25).

Generator Room--Ceiling debris (8 to 15 percent chrysotile asbestos) was present on the top of the ventilation ducts and the generator exhaust box and on the floors (Table B-25).

TABLE B-25. SUMMARY OF BULK SAMPLE RESULTS--SITE D 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
Electrical room	Top of electrical box	17% chrysotile asbestos
Electrical room	Top of fire alarm box	Positive[a] for chrysotile asbestos
Basement hallway at electrical room	Top of ceiling tile	18% chrysotile asbestos
Boiler room	Corner ledge	17% chrysotile asbestos
Generator room	Top of generator exhaust box	8% chrysotile asbestos
Generator room	Top of duct	13% chrysotile asbestos
Generator room	Floor at windows	15% chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Boiler Room--Ceiling debris (17 percent chrysotile asbestos) was present on the lower window ledge areas. The ladders provided were too unstable for safe access to such areas as the top of the air-handling unit and pipes (Table B-25).

Boiler Storage Room--Numerous 5-lb cans of asbestos sealant were noted in this area. These materials were due to be removed from inventory in 1989.

Corridor at the Electrical Room--The top of the suspended ceiling system was heavily contaminated with ceiling debris (18 percent chrysotile asbestos) (Table B-25). The wires, pipes, and ductwork in this space were covered with loose spray-on ceiling debris.

1988 Perimeter Areas

Time limitations prevented the inspection of these areas.

Other Considerations

The crawl space area in the boiler room was locked at the time of the inspection; however, in a gap between the wall and the deck of the boiler area, stored thermal system insulation with extensive water damage was noted. Opening the boiler room windows or activating the boiler air feeds could possibly have caused sufficient air movement to disturb these damaged materials. The school's Asbestos Management Plan indicated that these areas were scheduled for abatement in 1989; however, at the time of the 1991 inspection no abatement had occurred.

Conclusions

A likely source of the elevated airborne asbestos concentrations measured in May 1991 was the widespread spray-on ceiling dust and debris throughout the abatement areas. The debris found on top of the corridor ceilings and on the various equipment and ducts could indicate that the areas were not precleaned before erection of the polyethylene containment barriers.

Damaged material in the crawl space also may have contributed to the elevated asbestos levels. The NJDOH recommended that all other areas of the school, such as the loading dock, dumb-waiter, book storage, etc. be inspected for abatement residue, dust, and debris.

SITE E

Background

Site Description

During the summer of 1988, approximately 15,000 ft^2 of 2-ft by 4-ft lay-in ceiling tiles and approximately 500 linear feet of thermal system insulation (TSI) on pipes were removed from this school. The ceiling tiles were removed from classrooms, offices, and recreational areas; the TSI, from corridors. The ceiling tiles and TSI contained 2 to 8 percent amosite and 35 to 40 percent chrysotile asbestos, respectively. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. No additional abatement activity took place between 1988 and 1992.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area, and outdoors at approximately the same time and location as those collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-26 summarizes the results from the five sampling efforts. Figure B-5 illustrates the mean airborne asbestos concentrations at Site E. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-27. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-26. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE E[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0.001	0	0.005	0	0	0
Postabatement- 1988	0	0	0	0	0	0	0	0	0
Simulated occupancy-1990	0.004	0	0.011	0.006	0	0.016	0	0	0
Occupied conditions-1991	0.037	0.011	0.069	0.010	0	0.029	0.003	0	0.007
Occupied conditions-1992	0.009	0.007	0.011	0.007	0.003	0.011	0.004	0	0.010

[a] Samples were collected in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-27. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE E

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.3466	P(0.001) O(0)
Postabatement-1988	1.0	A(0) P(0) O(0)
Simulated occupancy-1990	0.1048	P(0.006) A(0.004) O(0)
Occupied conditions-1991	0.0069	A(0.037) P(0.010) O(0.003)
Occupied conditions-1992	0.0787	A(0.009) P(0.007) O(0.004)

[a] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

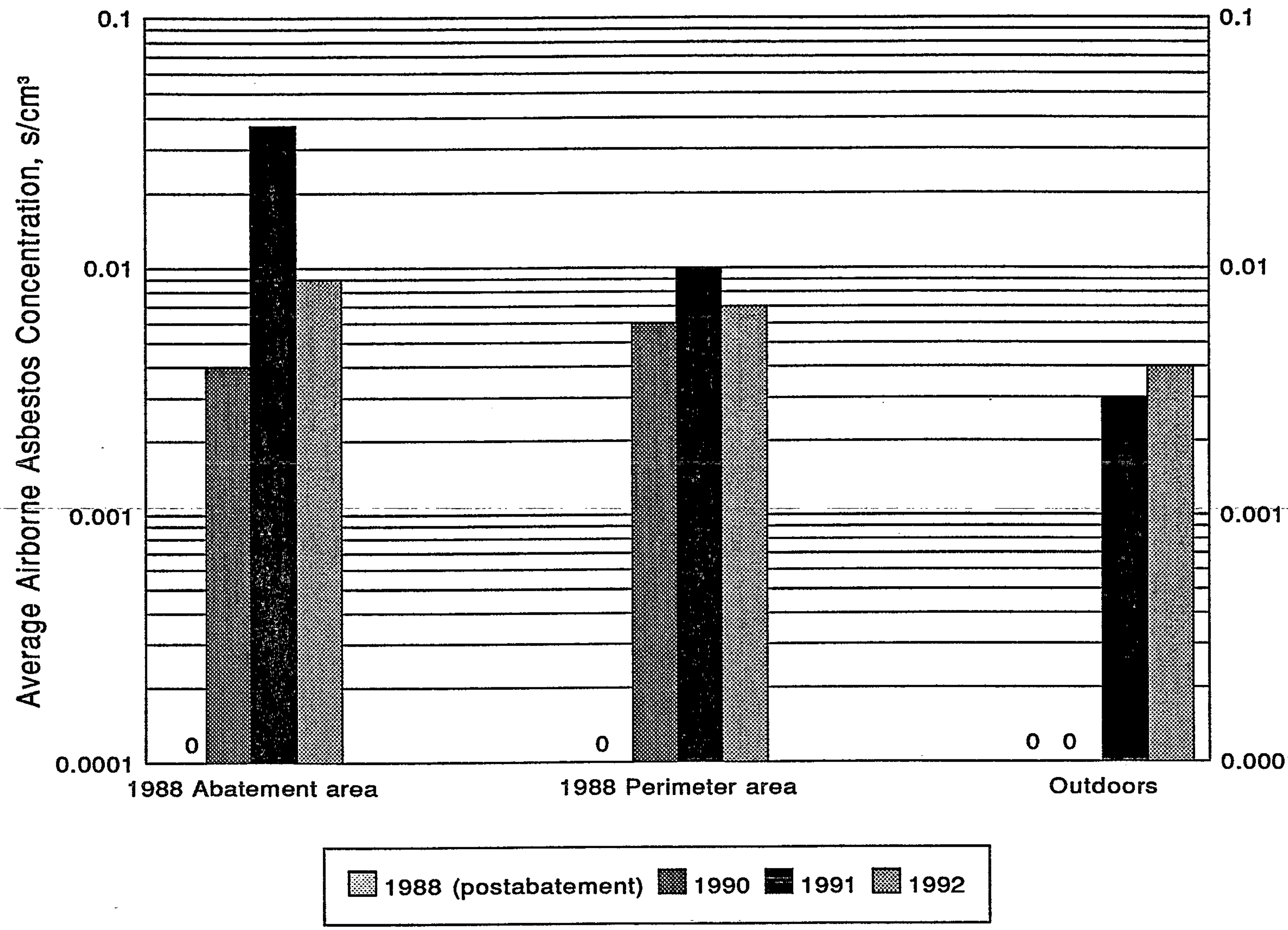

Figure B-5. Average airborne asbestos concentrations measured at Site E.

Summary of Air Monitoring Results

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement in 1988 was not significantly different from the average concentration measured outdoors.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (0 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.006 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.006 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.037 s/cm^3) was significantly greater than the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.010 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.037 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.010 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.009 s/cm^3) was significantly greater from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.009 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.007 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-28 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

The average airborne asbestos concentration measured in 1991 during occupied conditions (0.037 s/cm^3) was significantly greater than the average concentrations measured in 1988, 1990, and 1992. The average concentration measured in 1992 (0.009 s/cm^3) was significantly greater than the average concentration measured in 1988 (0 s/cm^3). Differences in average airborne asbestos concentrations measured in 1988 and 1990 and those measured in 1990 and 1992 were not statistically significant. The highest average concentration and the highest individual concentrations were measured during occupied conditions in 1991, 3 years after the 1988 abatement.

TABLE B-28. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE E

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0001	1991(0.037) 1992(0.009) 1990(0.004) 1988(0)
Perimeter area	0.0181	1991(0.010) 1992(0.007) 1990(0.006) 1988P(0.001) 1988(0)
Outdoors	0.0161	1992(0.004) 1991(0.003) 1990(0) 1988(0) 1988P(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, then the Tukey multiple comparison procedure was used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different statistically.

[e] 1988P = Preabatement; 1988 = Postabatement

Perimeter

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.01 s/cm^3) and the highest individual concentration (0.029 s/cm^3) were measured during occupied conditions in 1991, 3 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.004 s/cm^3) and the highest individual concentration (0.01 s/cm^3) were measured during occupied conditions in 1992, 4 years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-29 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20

TABLE B-29. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE E

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	0	-	-	-	-	-	-
	1990	4	100	0	25	0	25	50
	1991	54	98.1	1.9	13	1.9	16.7	68.5
	1992	17	100	0	47.1	0	17.6	35.3
Perimeter area	1988	0	-	-	-	-	-	-
	1990	6	100	0	0	0	50	50
	1991	14	100	0	50	7.1	0	42.9
	1992	12	100	0	58.3	0	0	41.7
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	5	100	0	100	0	0	0
	1992	6	100	0	83.3	0	0	16.7

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

collected outdoors yielded a total of 118 asbestos structures, 99.2 percent of which were chrysotile asbestos and 0.8 percent were amphibole. Overall, the asbestos structures were primarily matrices (50.8 percent), and to a lesser extent, fibers (33.9 percent), clusters (13.6 percent), and bundles (1.7 percent).

Table B-30 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 97.5 percent of the observed asbestos structures were less than 5 µm in length. Of these 40 asbestos fibers, none was greater than 5 µm in length.

Followup Air Monitoring - August 1991

Because the average airborne asbestos concentration in the previously abated area (0.037 s/cm^3) exceeded 0.02 s/cm^3 in May 1991, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 12, 1991, to determine whether airborne asbestos was still present at levels similar to those measured in May 1991. The August 12 results revealed that the average airborne asbestos concentration in the previously abated area was less than 0.02 s/cm^3 (0.005 s/cm^3); therefore, no further monitoring activity was required at this school. Intervention continued, however, to resolve the elevated airborne asbestos concentrations at this site.

NJDOH Visual Inspections

1988 Inspection

The NJDOH did not perform a visual inspection at this site. Upon completion of the final cleaning, the abatement contractor requested that a visual inspection be conducted by the onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification and did not identify any areas that required further cleaning.

1991 Inspection

On August 13, 1991, NJDOH conducted a visual inspection at Site E to determine potential sources of airborne asbestos measured by EPA/NJDOH in May 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined.

TABLE B-30. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE E

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	0	-	-	-	-	-	-
	1990	4	25	75	100	100	100	100
	1991	54	72.2	92.6	98.1	98.1	98.1	98.1
	1992	17	58.8	82.4	82.4	94.1	94.1	94.1
Perimeter area	1988	0	-	-	-	-	-	-
	1990	6	33.3	33.3	66.7	83.3	83.3	100
	1991	14	64.3	100	100	100	100	100
	1992	12	91.7	100	100	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	5	40	100	100	100	100	100
	1992	6	83.3	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

1988 Abatement Area

Corridors--The tops of the lockers contained small pieces of asbestos-containing ceiling tiles (Table B-31). At the end of each corridor (above the entry doors), an insulating barrier was constructed to separate the warm air in the corridor plenum from the cold air in the exterior foyer. The material in this barrier consisted of asbestos-containing plaster (7 percent chrysotile) over construction wire.

Art Storage Room--The TSI debris on top of the partition wall contained 5 percent chrysotile asbestos (Table B-31).

1988 Perimeter Area

Gymnasium--Asbestos-containing resilient floor tiles were noted.

Boiler Room--The TSI debris on the surface of the concrete-masonry block wall tested positive for asbestos (Table B-31). The TSI that remained on the interior surfaces of the "pork-chop" type boilers after abatement contained 2 to 5 percent chrysotile asbestos (Table B-31).

Conclusions

Asbestos-containing materials not included in the Asbestos Management Plan were found. These included a thermal insulating barrier (above the entry doors) at the end of each corridor and TSI lagging on the interior of the boiler.

The May 1991 monitoring revealed elevated concentrations of airborne asbestos. Because no amosite was present in any of the air samples, the source of the asbestos was material other than the ceiling tiles. These materials could have included unencapsulated debris from the 1988 abatement or the friable asbestos-containing insulating barrier above the entry doors.

TABLE B-31. SUMMARY OF BULK SAMPLE RESULTS -- SITE E 1991 INSPECTION

Location	Type of Material	Analysis
1988 Abatement Area		
Top of lockers at Room 109	Ceiling tile	<1% amosite
Top of lockers at Room 108	Ceiling tile	Trace[a] amosite
At exit by Room 108	Above drop ceiling	7% chrysotile
Top of locker #403	Ceiling tile	1% amosite
Top of lockers at Room 111	Ceiling tile	1% amosite
Top of locker at boiler room	Ceiling tile	1% amosite
Art storage room	Partition wall	5% chrysotile
1988 Perimeter Areas		
Boiler room	Lagging inside boiler	5% chrysotile
Boiler room	Lagging inside boiler	2% chrysotile
Boiler room	TSI debris on wall	Trace chrysotile

[a] Trace = <1 percent asbestos.

SITE F

Background

Site Description

During the summer of 1988, approximately 2200 ft^2 of thermal system insulation (TSI) on the boiler, boiler breeching, and pipes was removed from the boiler room in the 1955 wing at this school. The TSI contained approximately 30 to 40 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. There has been no additional abatement activity took place between 1988 and 1991. In April 1992, thermal system insulation and asbestos-containing resilient floor tile (and mastic) were removed from the cafeteria and music room of the 1923 Wing. In July 1992, asbestos-containing resilient floor tile (and mastic) were removed from hallways of the 1955 Wing. Ceiling tiles also may have been removed in three classrooms (Rooms 20, 22, and 23) in July 1992. The 1923 Wing underwent a major renovation of the cafeteria, including installation of an elevator system.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as those collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-32 summarizes the results from the four sampling efforts. Figure B-6 shows the mean airborne asbestos concentrations at Site F. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-33 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-32. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE F[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0.003	0	0.008	0	0	0
Postabatement-1988	0.024	0.009	0.052	0.002	0	0.009	0.001	0	0.003
Simulated occupancy-1990	0.001	0	0.005	0.005	0	0.024	0	0	0
Occupied conditions-1991	0.043	0.032	0.066	0.036	0.010	0.058	0.001	0	0.002
Occupied conditions-1992	0.036	0.025	0.042	0.037	0.005	0.062	0.002	0	0.008

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-33. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE F

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.1456	P(0.003) O(0)
Postabatement-1988	0.0003	A(0.024) P(0.002) O(0.001)
Simulated occupancy-1990	0.5616	P(0.005) A(0.001) O(0)
Occupied conditions-1991	0.0001	A(0.043) P(0.036) O(0.001)
Occupied conditions-1992	0.0002	P(0.037) A(0.036) O(0.002)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

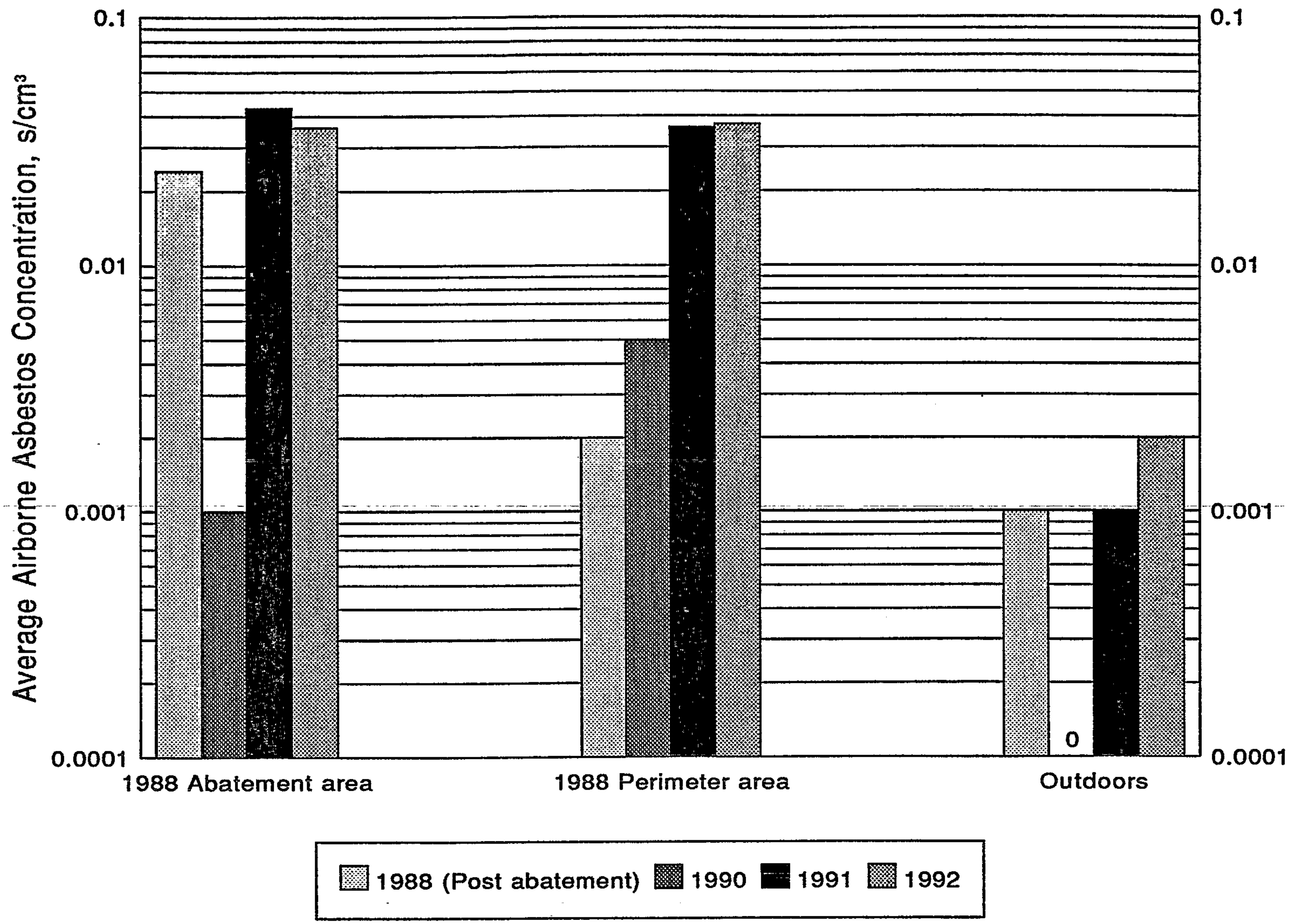

Figure B-6. Average airborne asbestos concentrations measured at Site F.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (215 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by use of the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.024 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.024 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.001 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.005 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.043 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.036 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.043 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.036 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.036 s/cm^3) was significantly greater than the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.037 s/cm^3) was significantly greater than the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.036 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.037 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-34 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

The differences between average airborne asbestos concentrations measured in 1988, 1991, and 1992 were not statistically significant. The average airborne asbestos concentration measured in 1990 (0.001 s/cm^3) was, however, significantly less than average concentrations measured in 1988, 1991, and 1992. The highest average airborne asbestos concentration (0.043 s/cm^3) and highest individual concentration (0.066 s/cm^3) were measured during occupied conditions in 1992, four years after the 1988 abatement.

1988 Perimeter Area

The average airborne asbestos concentrations measured during occupied conditions in 1991 (0.036 s/cm^3) and 1992 (0.037 s/cm^3) were not significantly different; however, they were significantly greater than the average concentrations measured in 1988 and 1990. The average preabatement concentration (0.003 s/cm^3) and postabatement concentration (0.002 s/cm^3) in 1988 were not significantly different from the concentration measured in 1990 (0.005 s/cm^3). The highest average airborne asbestos concentration (0.037 s/cm^3) and individual concentration (0.062 s/cm^3) were measured during occupied conditions in 1992, four years after the 1988 abatement.

TABLE B-34. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE F

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0001	1991(0.043) 1992(0.036) 1988(0.024) 1990(0.001)
Perimeter area	0.0001	1992(0.037) 1991(0.036) 1990(0.005) 1988P(0.003) 1988(0.002)
Outdoors	0.0816	1992(0.002) 1988(0.001) 1991(0.001) 1990(0) 1988P(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.002 s/cm^3) and the highest individual concentration (0.008 s/cm^3) were measured during occupied conditions in 1992, four years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-35 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 318 asbestos structures, of which 99.1 percent were chrysotile asbestos and 0.9 percent were amphibole. Overall, the asbestos

TABLE B-35. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE F

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	42	100	0	81.0	4.8	0	14.3
	1990	1	100	0	0	100	0	0
	1991	61	100	0	34.4	16.4	4.9	44.3
	1992	77	97.4	2.6	45.5	15.6	3.9	35.1
Perimeter area	1988	3	100	0	100	0	0	0
	1990	5	100	0	80	0	20	0
	1991	52	100	0	25	7.7	3.8	63.5
	1992	70	100	0	37.1	5.7	5.7	51.4
Outdoors	1988	1	0	100	100	0	0	0
	1990	0	-	-	-	-	-	-
	1991	1	100	0	100	0	0	0
	1992	5	100	0	80	0	0	20

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

structures were primarily fibers (44.7 percent) and matrices (40.9 percent), and to a lesser extent, bundles (10.4 percent) and clusters (4.1 percent).

Table B-36 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 96.2 percent of the observed asbestos structures were less than 5 µm in length. Of the 142 asbestos fibers, only 4 (2.8 percent) were greater than 5 µm in length.

Followup Air Monitoring - August 1991

Because the average airborne asbestos concentration in the previously abated area (0.043 s/cm^3) and in the perimeter area (0.036 s/cm^3) exceeded 0.02 s/cm^3 in May 1991, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 12, 1991, to determine whether airborne asbestos was still present at levels similar to those measured in May 1991. The average airborne asbestos concentrations in both the previously abated area (0.024 s/cm^3) and the perimeter area (0.023 s/cm^3) still exceeded 0.02 s/cm^3; therefore, NJDOH directed the school to initiate a response action to reduce the airborne asbestos concentrations in these areas. When the cleaning action was complete, EPA/NJDOH conducted followup air monitoring on August 28, 1991. The average airborne asbestos concentrations in the previously abated area and in the perimeter area were below 0.02 s/cm^3; therefore, no further monitoring activity was required at this site. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

Followup Air Monitoring - August 1992

Because the average airborne asbestos concentration in the previously abated area (0.036 s/cm^3) and in the perimeter area (0.037 s/cm^3) in May 1992 exceeded 0.02 s/cm^3, NJDOH-EHS required response action at this school. The school subsequently employed a licensed asbestos-abatement contractor to clean the previously abated and perimeter areas. When the cleaning action was complete, NJDOH conducted followup air monitoring in September 1992 to determine the residual levels of airborne asbestos in the perimeter area. The average airborne asbestos concentration in the perimeter area (0.07 s/cm^3) still exceeded 0.02 s/cm^3; therefore, further cleaning was required. After the additional cleaning was complete, the school's consultant conducted followup air monitoring in the previously abated area and the perimeter area. The average airborne asbestos concentration in both areas (0.004 s/cm^3) was below 0.02 s/cm^3; therefore, no further monitoring activity was required.

TABLE B-36. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE F

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	42	54.8	95.2	97.6	97.6	97.6	100
	1990	1	0	0	0	0	0	100
	1991	61	54.1	88.5	96.7	96.7	96.7	98.4
	1992	77	64.9	88.3	92.2	92.2	93.5	100
Perimeter area	1988	3	66.7	100	100	100	100	100
	1990	5	40	80	100	100	100	100
	1991	52	48.1	78.8	94.2	98.1	98.1	100
	1992	70	57.1	72.9	98.6	98.6	98.6	98.6
Outdoors	1988	1	0	0	0	0	0	100
	1990	0	-	-	-	-	-	-
	1991	1	100	100	100	100	100	100
	1992	5	20	80	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

NJDOH Visual Inspections

1988 Inspection

The NJDOH did not perform a visual inspection at this site. Upon completion of the final cleaning, the abatement contractor requested that a visual inspection be conducted by the onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification, and did not identify any areas that required further cleaning.

Background for 1991 and 1992 Inspections

On August 13, 1991, and July 15, 1992, NJDOH conducted a visual inspection at Site F to determine potential sources of airborne asbestos measured by EPA/NJDOH in May 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined.

1991 Inspection

1988 Abatement Area

In the boiler room, asbestos-containing TSI (29 percent chrysotile asbestos) was found on the interior of the boiler. The asbestos-containing TSI on the exterior of the boiler had been removed, and the boiler had been reinsulated.

1988 Perimeter Areas

Hallway at the Boiler Room Entry--The school's Asbestos Management Plan indicated the presence of sprayed-on asbestos above the interlock ceiling in this area. No sprayed-on materials were noted; however, four different-sized homogeneous pipe runs were observed that were not included in the Asbestos Management Plan. The school's Asbestos Management Plan appeared to be in error regarding the types of material and their locations. Approximately 10 linear feet of this pipe insulation was torn from the pipes directly below an open roof vent.

School officials indicated that during a retrofit of the school's fire alarm system, workers had crawled through the suspended ceiling plenums to run wires. Such activity may have caused a fiber release and/or damage to the thermal materials. A roof leak and subsequent repair also may have contributed to the TSI damage.

Air-Handling Rooms in Gymnasium--Thermal system insulation was removed from these areas. A thick accumulation of dust mixed with flakes of elbow debris (positive, chrysotile asbestos) was present on the air-handling unit (Table B-37). The duct sealant contained 49 percent chrysotile asbestos. The duct sealant had been abated in the north air-handling room, but was only partly abated in the south air-handling room. Gouged friable sealant remained on the ducting and was not encapsulated.

Classrooms--The two classrooms farthest from the boiler area (Classrooms 42 and 43) were inspected for the presence of asbestos-containing debris. Both rooms had heater units equipped with blowers and external air exchangers. Thermal system insulation had been removed from the pipes in the closets adjoining these units. Asbestos-containing debris (30 to 36 percent chrysotile and trace to 4 percent amosite) was recovered from the base of the units (Table B-37).

Conclusions

The school's Asbestos Management Plan did not reflect the residual asbestos in the boilers. This material probably would be disturbed during cleaning by aggressive brushing and vacuuming of the interior to remove the carbonaceous deposits.

The Asbestos Management Plan was in error regarding the types of materials above the hallway at the boiler room entry. The 10-ft of severely damaged TSI resulting from a roof leak and the installation of electrical cable in the plenum above the hallway may have resulted in a release of asbestos fibers from the damaged TSI.

The asbestos-containing TSI debris collected in the air-handling rooms and classrooms indicated that these areas may have been contaminated as the result of incomplete abatement action. The asbestos-containing debris may have been reentrained by the air-handling system or the normal activity of building occupants. Operations and maintenance activities on floor tiles located in the perimeter areas may have also contributed to the elevated airborne asbestos levels.

1992 Inspection

1988 Abatement Area

Boiler Room--The friable thermal system insulation sampled during the August 1991 visual inspection was still present in the interior of the boiler. The cementitious ceiling material in the boiler room did not contain asbestos (Table B-38).

1988 Perimeter Area

Stage (1955 Wing)--Scraps of asbestos-containing floor tile was used to shim the lath of the suspended ceiling systems.

TABLE B-37. SUMMARY OF BULK SAMPLE RESULTS--SITE F 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
Boiler room	Interior of Boiler 24	29% chrysotile asbestos
1988 Perimeter Areas		
SE air handling room, gymnasium	Debris on top of air handler	Positive[a], chrysotile asbestos
SE air handling room, gymnasium	Remaining duct sealant	49% chrysotile asbestos
Classroom 42	TSI debris in closet under heating unit	30% chrysotile asbestos 4% amosite asbestos
Classroom 43	TSI debris in closet under heating unit	36% chrysotile asbestos Trace[b], amosite asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

[b] Trace = <1 percent asbestos.

Corridors (1955 Building Wing)--Damaged asbestos-containing thermal system insulation was present in the air plenum above the dropped ceiling in the hallways of the 1955 wing (Table B-38). The debris noted during the 1991 NJDOH inspection had only been partially abated. This debris tested positive for asbestos as did the other homogeneous thermal system insulation of pipes. These insulating materials were not listed in the Asbestos Management Plan prepared in 1988. The Management Plan inaccurately identified sprayed-on material in this area.

Utility Chase (1955 Building Wing)--Asbestos-containing TSI debris was noted on the dirt floor in the utility chase (accessible through the floor hatch in the janitor's closet) that runs under the floor of the 1955 Wing (Table B-38).

Stairwell by Gym (1923 Building Wing)--No positive materials were recovered from the immediate area, however, the plaster of the ceiling system had been severely damaged by water leaving a hole of approximately ten square feet. The area above this, an attic plenum, had been constructed of nonfriable transite type asbestos sheeting. Several linear feet of friable and damaged trowel-applied asbestos-containing material was observed in this plenum where metal conduits bend downward and penetrate through the floor (Table B-38). The corner joints of the transite plenum had also been spackled with a trowel-applied asbestos-containing mud (Table B-38). These materials were not noted in the Asbestos Management Plan or in the 3-year reinspection report.

Lavatories (1960 Addition-adjacent to 1923 Wing)--Thermal system insulation was observed on the elbows of the fan/duct system in each lavatory. Generally the material appeared to be in good condition. The 1960 addition and the thermal system insulation materials did not appear in the Management Plan or the three year reinspection. Some abatement may have taken place in this area in 1988. The addition utilized materials that "matched" the materials of the 1923 wing, however this area was not listed in the Management Plan.

Gymnasium Air-Handling Room (1955 Building Wing)--Friable asbestos-containing duct sealant (paper type) and associated sealant debris were noted in the air-handling rooms (Table B-38). These partially abated materials were also noted during the August 1991 visual inspection. Sealant debris was also present in the cavities of the concrete-masonry blocks.

Janitor's Office/Old Boiler Room--Asbestos-containing debris was noted in a wall penetration from the hallway (Table B-38).

North-East Stairwell (1923 Wing)--This area had corrugated pipe insulation, sealed in part by a metal jacket and several old layers of paint. This material did not appear in the Management Plan or in the three year re-inspection report.

TABLE B-38. SUMMARY OF BULK SAMPLE RESULTS - SITE F 1992 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Area		
Boiler room	Cement ceiling	Negative
1988 Perimeter Areas		
1923 Stairwell by gym	Plaster, top coat, ceiling	Negative
1923 Stairwell by gym	Plaster, browncoat, ceiling	Negative
Stage overhead	VAT chips to shim lath	17% Chrysotile asbestos
1955 Hallway plenum at boiler room	Pipe debris - outer layer	17% Chrysotile asbestos
1955 Hallway plenum at boiler room	Pipe debris - mid layer	1% Chrysotile asbestos
1955 Hallway plenum at boiler room	Pipe debris - bottom layer	Negative
1955 Hallway plenum at boiler room	8" Line, block insulation	8% Amosite asbestos
1955 Hallway plenum at boiler room	3" Line, corrugated	33% Chrysotile asbestos
1955 Hallway plenum, west hall	"Balsam-wood" pillow	Negative
Stage air-handling room SE	Duct debris in block	42% Chrysotile asbestos
Stage air-handling room NW	Duct, residual	41% Chrysotile asbestos
1923 Attic plenum	Pipe bedding	20% Chrysotile asbestos
1923 Attic plenum	Mud caulk to seal transite	16% Chrysotile asbestos
1923 Attic plenum	Transite type sheeting	8% Chrysotile asbestos
1923 Attic plenum	Soft sheeting	21% Chrysotile asbestos
1955 Classroom #33, closet	Debris at heater/pipe entry	23% Chrysotile asbestos Trace, amosite
1955 Classroom #32, closet	Debris at heater/pipe entry	7% Chrysotile asbestos Trace[a], amosite asbestos
1955 Classroom #30, closet	Debris at heater/pipe entry	Positive[b] Chrysotile asbestos
1955 Custodian room, below grade	Debris, corrugated insulation	25% Chrysotile asbestos
1923 Wing old boiler room	Debris, block insulation in penetration	1% Chrysotile asbestos 7% Amosite asbestos

[a] Trace = <1 percent asbestos

[b] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Conclusions

A number of asbestos sources were identified in various areas of the building that could have contributed to the elevated asbestos levels measured in May 1992. The school's Asbestos Management Plan must be revised to reflect the presence of these materials.

Elevated air levels in the first-floor hallway (1955 wing) could have been caused by damaged friable asbestos-containing material in the air plenum above the dropped ceiling. Under certain environmental conditions of wind direction and velocity, air could flow from the plenum through the louvered ceiling vents into the hallway. Workers who installed the smoke detectors and connecting cable in the hallway ceiling or who periodically service the system could have disturbed the asbestos-containing material and caused a fiber-release episode. Air from the third-floor plenum, where several types of asbestos-containing materials were identified, could flow into occupied areas and the nearby stairwell under certain environmental conditions.

The elevated levels in the boiler room could be attributed to resuspended residual debris that was not completely removed during abatement. The elevated levels also could be from air infiltration from the first-floor ceiling plenum or classrooms.

SITE G

Background

Site Description

The abatement project at this two-story school building involved the removal of asbestos-containing thermal insulation materials (i.e., boiler lagging, boiler breeching, and boiler gaskets) on the boiler and mechanical equipment. The project specifications indicated that the asbestos content of the boiler lagging was 10 to 15 percent chrysotile and 35 to 40 percent amosite; the asbestos content of the boiler breeching was 25 to 30 percent chrysotile and 30 to 35 percent amosite; and the asbestos content of the boiler gasket was 70 to 75 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. The project specifications did not quantify the amount of asbestos-containing material in each location.

Air Monitoring Summary

In 1988, post-abatement air samples were collected in the abatement area, the perimeter area, and outdoors at approximately the same time and location as those collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter area and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Figure B-7 shows the mean airborne asbestos concentrations at Site G. Table B-39 summarizes the results from the five sampling efforts. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-40. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

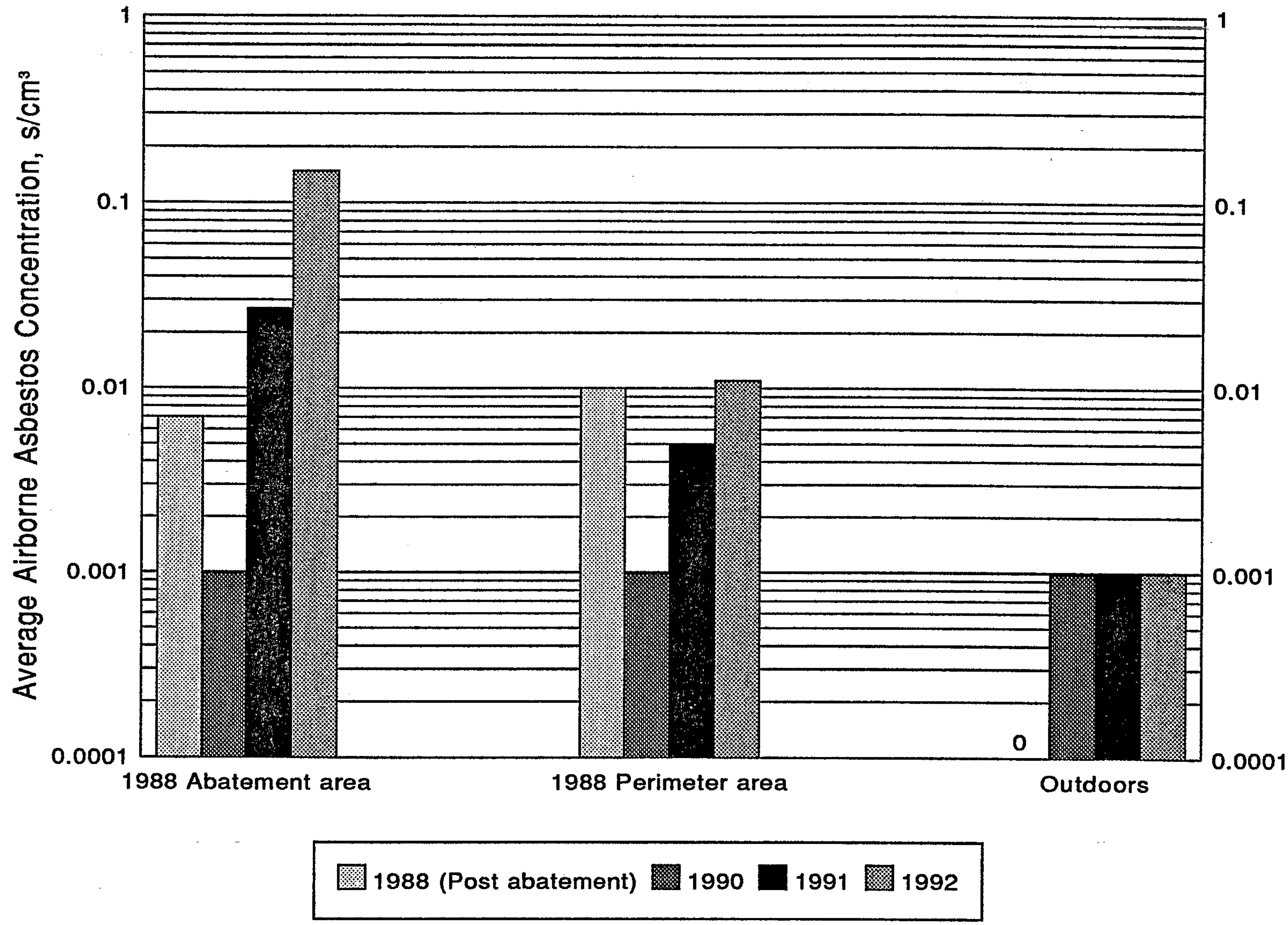

Figure B-7. Average airborne asbestos concentrations measured at Site G.

TABLE B-39. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE G

Sampling period	Abatement area (N=5)			Perimeter Area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0	0	0	0	0	0
Postabatement-1988	0.007	0	0.022	0.010	0	0.026	0	0	0
Simulated occupancy-1990	0.001	0	0.005	0.001	0	0.005	0.001	0	0.005
Occupied conditions-1991	0.027	0.011	0.037	0.005	0	0.011	0.001	0	0.004
Occupied conditions-1992	0.148	0.108	0.236	0.011	0	0.033	0.001	0	0.003

[a] Samples were collected each year in the 1988 abatement and perimeter areas, and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-40. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE G

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	1.0	P(0) O(0)
Postabatement-1988	0.1003	P(0.010) A(0.007) O(0)
Simulated occupancy-1990	1.0	A(0.001) P(0.001) O(0.001)
Occupied conditions-1991	0.0005	A(0.027) P(0.005) O(0.001)
Occupied conditions-1992	0.0001	A(0.148) P(0.011) O(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (51 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.010 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.007 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.010 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.001 s/cm^3) was not significantly different from the average outdoor concentration (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.027 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.027 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.005 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area with Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.148 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.011 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.148 s/cm^3) was significantly greater than the average concentration measured in the perimeter area (0.011 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-41 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The following subsections summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-41. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE G

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0001	1992(0.148) 1991(0.027) 1988(0.007) 1990(0.001)
Perimeter area	0.2346	1992(0.011) 1988(0.010) 1991(0.005) 1990(0.001) 1988P(0)
Outdoors	0.5623	1991(0.001) 1990(0.001) 1992(0.001) 1988(0) 1988P(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement

1988 Abatement Area

The average airborne asbestos concentrations measured in 1988 and 1990 were not significantly different. The average concentration measured during occupied conditions in 1991 (0.027 s/cm^3) was significantly greater than the average concentrations measured in 1988 (0.007 s/cm^3) and 1990 (0.001 s/cm^3). The average concentration measured in 1992 (0.148 s/cm^3) was significantly greater than average concentrations measured in 1988, 1990, and 1991. The highest average concentration (0.148 s/cm^3) and the highest individual concentration (0.236 s/cm^3) were measured during occupied conditions in 1992, four years after abatement.

1988 Perimeter Area

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.011 s/cm^3) and the highest individual concentration (0.033 s/cm^3) were measured during occupied conditions in 1992, four years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.001 s/cm^3) and the highest individual concentration (0.005 s/cm^3) were measured during simulated occupancy in 1990, two years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-42 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 382 asbestos structures, of which 96.6 percent were chrysotile asbestos and 3.4 percent were amphibole. Overall, the asbestos structures were primarily fibers (90.1 percent), and to a lesser extent, matrices (7.1 percent), bundles (2.4 percent), and clusters (0.5 percent).

Table B-43 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 96.1 percent of the observed asbestos structures were less than 5 µm in length. Of the 344 asbestos fibers observed, only 12 (3.5 percent) were greater than 5 µm in length.

TABLE B-42. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE G

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	10	50	50	90	0	0	10
	1990	1	100	0	100	0	0	0
	1991	37	100	0	94.6	0	0	5.4
	1992	285	100	0	92.6	2.8	0	4.6
Perimeter area	1988	14	50	50	57.1	7.1	14.3	21.4
	1990	1	100	0	100	0	0	0
	1991	7	100	0	57.1	0	0	42.9
	1992	23	100	0	78.3	0	0	21.7
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	2	100	0	100	0	0	0
	1992	1	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-43. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE G

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	10	0	20	40	40	40	60
	1990	1	0	0	0	0	0	100
	1991	37	89.2	97.3	100	100	100	100
	1992	285	76.8	97.9	100	100	100	100
Perimeter area	1988	14	0	0	21.4	35.7	50	85.7
	1990	1	100	100	100	100	100	100
	1991	7	42.9	71.4	100	100	100	100
	1992	23	69.6	91.3	100	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	1	0	0	0	0	0	100
	1991	2	50	100	100	100	100	100
	1992	1	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Followup Air Monitoring - August 1991

Because the average airborne asbestos concentration in the previously abated area (0.027 s/cm^3) exceeded 0.02 s/cm^3 in May 1991, EPA/NJDOH conducted follow-up monitoring under simulated occupancy conditions on August 14, 1991, to determine whether airborne asbestos was still present in the concentrations measured in May 1991. The average airborne asbestos concentrations in both the previously abated area (0.048 s/cm^3) and in the perimeter area (0.063 s/cm^3) exceeded 0.02 s/cm^3; therefore, NJDOH directed the school to initiate a response action to reduce the airborne asbestos concentrations in these areas. The school subsequently used trained in-house staff to clean these areas.

When the cleaning action was complete, EPA/NJDOH conducted follow-up air monitoring on August 26, 1991, to determine the residual levels of airborne asbestos. The average airborne asbestos concentrations in the previously abated and perimeter areas were below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

Followup Air Monitoring - August 1992

Because the average airborne asbestos concentration in the previously abated area (0.148 s/cm^3) in May 1992 exceeded 0.02 s/cm^3, NJDOH-EHS required response action at this school. The school subsequently used in-house staff to clean the previously abated and perimeter areas. When the cleaning action was complete, EPA/NJDOH conducted followup air monitoring in August 1992 to determine the residual levels of airborne asbestos. The average airborne asbestos concentrations in the previously abated area (0.006 s/cm^3) and perimeter area (0.002 s/cm^3) were both below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school.

NJDOH Visual Inspections

1988 Inspection

The NJDOH did not perform a visual inspection at this site. Upon completion of the final cleaning, the abatement contractor requested that a visual inspection be conducted by the onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification and did not identify any areas that required further cleaning.

Background for 1991 and 1992 Inspections

On August 15, 1991, and July 17, 1992, a NJDOH visual inspection was conducted at Site G to determine potential sources of airborne asbestos concentrations measured by EPA/NJDOH in May 1991 and May 1992, respectively. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in August 1991 and July 1992.

1991 Inspection

1988 Abatement Area

All areas examined revealed contamination from abatement activities. Wall penetrations, pipe hangers, tops of tanks, wiring, and electrical panels were all contaminated with residual material and debris (Table B-44).

1988 Perimeter Area

Various areas throughout the school (classrooms and offices) were undergoing renovation at the time of the inspection. Plaster walls were being demolished, which left many areas coated with plaster dust. According to the Asbestos Management Plan, one of two plaster samples tested positive (1 percent) for asbestos. Several samples collected during the inspection, however, showed no detectable levels of asbestos in either the top-coat or browncoat layer (Table B-44).

Conclusions

The elevated airborne asbestos concentrations measured in May 1991 may be due to the residual asbestos-containing material and debris on surfaces in the boiler room remaining from the 1988 abatement. The perimeter air samples contained chrysotile asbestos. It was originally thought that the wall demolition (as specified by the Management Plan) was the primary contributor to the elevated air levels. This, however, was not supported by the analysis of bulk samples.

1992 Inspection

1988 Abatement Area

As noted during the 1991 visual inspection, all areas examined in the boiler room revealed contamination from the 1988 abatement activities. Wall penetrations, holes, pipe hangers, top of tanks, wiring, and electrical panels were all contaminated with residual asbestos-containing material and debris (Table B-45). The residual asbestos-containing spray-on ceiling material was encapsulated with a thin coat of

TABLE B-44. SUMMARY OF BULK SAMPLE RESULTS - SITE G 1991 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Areas		
Boiler room	Wall, slurry at extension tank	7% Chrysotile asbestos 8% Amosite asbestos
Boiler room	Wall, slurry on conduit	8% Chrysotile asbestos 4% Amosite asbestos
Boiler room	Remaining insulation on tank	42% Chrysotile asbestos
Boiler room	Debris, top of Devlin Elec. Unit	2% Chrysotile asbestos 19% Amosite asbestos
Boiler room	Debris, brace of Devlin Unit	1% Chrysotile asbestos 25% Amosite asbestos
Boiler room	Debris, pipe hangers	34% Chrysotile asbestos
Boiler room	Debris, pipe penetration to hallway	<1% Chrysotile asbestos 18% Amosite asbestos
Boiler room	Debris, sprinkler box	3% Chrysotile asbestos 24% Amosite asbestos
Boiler room	Residue, hole in ceiling	1% Chrysotile asbestos 16% Amosite asbestos
Boiler room	Debris, pipe penetration, janitors office	2% Chrysotile asbestos 22% Amosite asbestos
Boiler room	Residue, ceiling penetration	Positive[a], amosite asbestos
1988 Perimeter Areas		
West office	Plaster and browncoat	Negative
Storage by Room 312	Plaster and browncoat	Negative
Room between 311 and 312	Plaster and browncoat	Negative
Third-floor rear corridor	Plaster and browncoat	Negative
Third-floor rear (NE) room	Insulation, below floors	Negative
First-floor corridor	Blackboard slate, debris	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

TABLE B-45. SUMMARY OF BULK SAMPLE RESULTS - SITE G 1992 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Area		
Under Baldor pump behind boilers	Thermal debris	2% chrysotile asbestos 5% amosite asbestos
Under Baldor pump behind boilers	Thermal debris	3% chrysotile asbestos 3% amosite asbestos
Above Domestic Vac unit behind tank	Thermal debris	19% chrysotile asbestos
Above Domestic Vac unit behind tank	Thermal debris	40% chrysotile asbestos
Brace of small expansion tank	Thermal debris	40% chrysotile asbestos
Floor trap by janitors office, left side	Dirt and spray-on debris	9% amosite asbestos
Floor trap by janitors office, right side	Dirt and spray-on debris	<3% (0.9%) chrysotile asbestos 21% amosite asbestos
Small expansion tank brace	Debris	Positive[a] chrysotile asbestos Positive amosite asbestos
Boiler 1 caulk, front of unit	Grey, nonfriable	4% chrysotile asbestos
Boiler 1, rear of unit	Pink refractory cement	Negative
Boiler 1, delaminated seam	Dirt and scale	Negative
Boiler 2, rear of unit	Refractory debris	Negative
Boiler 2, rear of unit	Soot and refractory	Negative
Boiler 1, front of unit	Soot from combustion tubes	Negative
Beam at Taco unit	Spray-on residue	Positive, amosite asbestos
Electrical box by Taco unit	Spray-on residue	1% chrysotile asbestos 20% amosite asbestos
Electrical box by Taco unit	Spray-on residue	1% chrysotile asbestos 15% amosite asbestos
Pipe brace above Taco unit	Spray-on residue	1% chrysotile asbestos 6% amosite asbestos
Beam by boilers	Spray-on residue	0.9% chrysotile asbestos 8% amosite asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples of which there is not adequate material available to allow a full quantitative evaluation, but are of sufficient size to determine that asbestos is present and to determine the specific type of asbestos. Based on the professional judgement of the analyst, the sample is considered to contain greater than 1 percent asbestos.

paint, which was peeling (Table B-45). The boiler soot, refractory debris, or delaminating insulation seam did not contain detectable levels of asbestos (Table B-45).

Conclusions

As noted during the 1991 visual inspection, the primary source of the elevated airborne asbestos concentrations measured in May 1991 was from the residual asbestos-containing material and debris on surfaces in the boiler room remaining from the 1988 abatement. Remedial actions in 1991 relied on encapsulating the residual spray-on material with paint, which failed to correct the conditions adequately in the boiler room. Conditions still exist that could cause periodic fiber-release episodes during routine O&M activities in the boiler room.

SITE H

Background

Site Description

During the summer of 1988, asbestos-containing acoustical ceiling plaster, spray-applied fireproofing, and thermal system insulation (TSI) were removed from Site H. The abatement area included corridors and adjacent vestibules, classrooms, offices, and recreational rooms. The acoustical plaster, fireproofing, and TSI contained 10 to 25 percent, 25 to 50 percent, and 40 to 60 percent chrysotile asbestos, respectively. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. No additional abatement activity occurred between 1988 and 1992.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as the samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-46 summarizes the results of the four sampling efforts. Figure B-8 shows the mean airborne asbestos concentrations at Site H. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-47 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-46. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE H[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.016	0.008	0.045	0.062	0.012	0.206	0.003	0	0.012
Simulated occupancy-1990	0	0	0	0	0	0	0	0	0
Occupied conditions-1991	0.030	0	0.102	0.005	0	0.011	0.003	0	0.006
Occupied conditions-1992	0.007	0	0.018	0.025	0.006	0.089	0.001	0	0.007

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-47. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE H[a]

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0069	P(0.062) A(0.016) O(0.003)
Simulated occupancy-1990	1.0	A(0) P(0) O(0)
Occupied conditions-1991	0.1078	A(0.030) P(0.005) O(0.003)
Occupied conditions-1992	0.0203	P(0.025) A(0.007) O(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

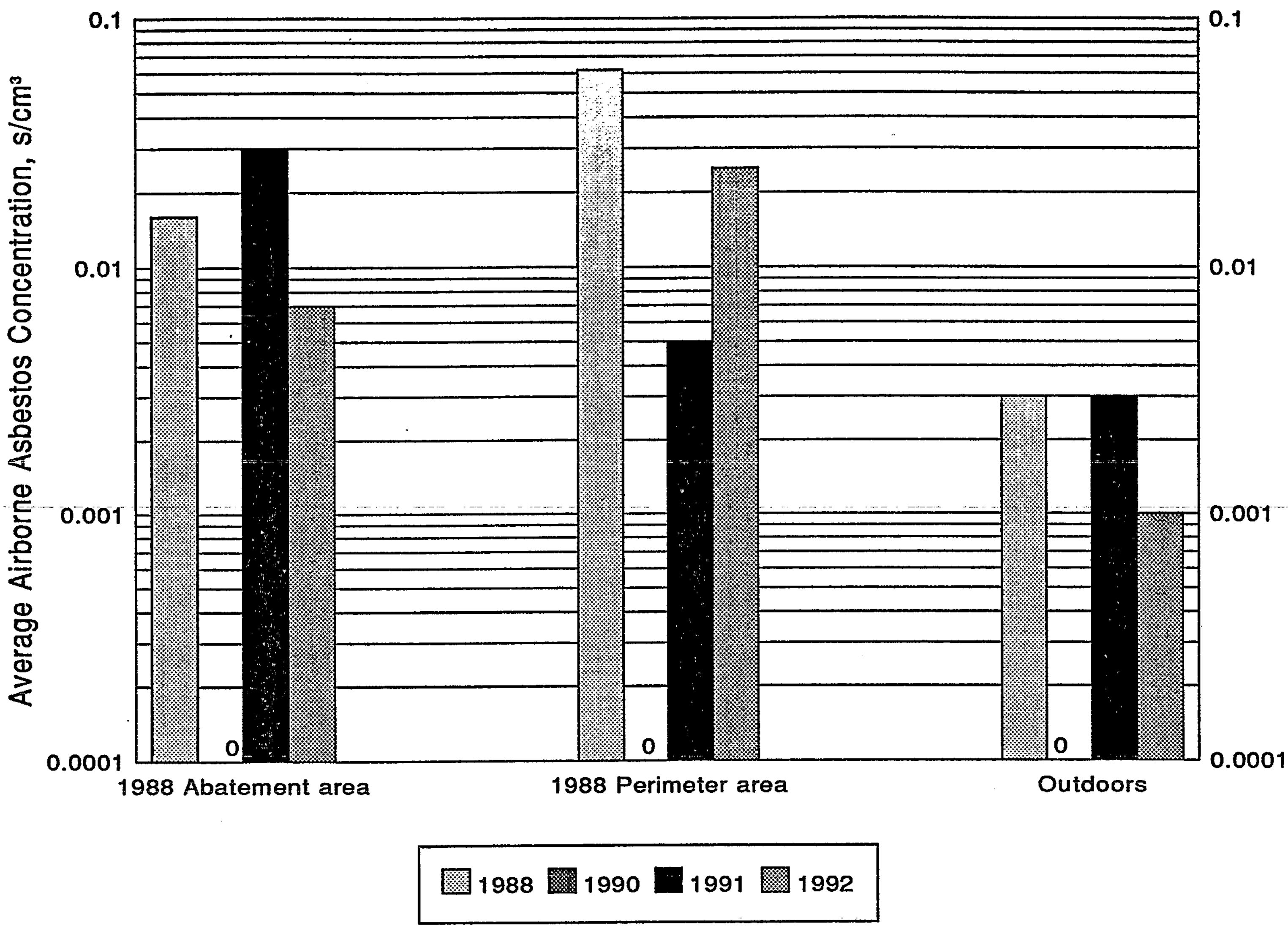

Figure B-8. Average airborne asbestos concentrations measured at Site H.

Summary of Air Monitoring Results

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (106 s/mm^2) exceeded 70 s/mm^2. The site would have passed the AHERA Z-test, however, regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results and would have passed the AHERA clearance test by using the EPA/NJDOH results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.016 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.062 s/cm^3) was significantly greater than the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.016 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.062 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.030 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.030 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.005 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.025 s/cm^3) was significantly greater than the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.025 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-48 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. Subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-48. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE H

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0057	1991(0.030) 1988(0.016) 1992(0.007) 1990(0)
Perimeter	0.0005	1988(0.062) 1992(0.025) 1991(0.005) 1990(0)
Outdoors	0.2083	1988(0.003) 1991(0.003) 1992(0.001) 1990(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

The average airborne asbestos concentration measured in 1988 (0.016 s/cm^3) was significantly greater than the average concentration measured in 1990 (0 s/cm^3). Differences between average levels measured in 1990, 1991, and 1992 were not statistically significant. Similarly, differences between average levels measured in 1988, 1991, and 1992 were not statistically significant. The highest average concentration (0.016 s/cm^3) and the highest individual concentration (0.045 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter

The average airborne asbestos concentration measured during the AHERA clearance phase of the 1988 abatement (0.062 s/cm^3) was significantly greater than the average levels measured in 1990 (0 s/cm^3), 1991 (0.005 s/cm^3), and 1992 (0.025 s/cm^3). Differences between average levels measured in 1990, 1991, and 1992 were not statistically significant. The highest average (0.062 s/cm^3) and highest individual (0.206 s/cm^3) concentrations were measured during the AHERA clearance phase of the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.003 s/cm^3) and the highest individual concentration (0.012 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-49 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 181 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (70.2 percent), and to a lesser extent, matrices (22.1 percent), bundles (6.1 percent), and clusters (1.7 percent).

Table B-50 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 97.2 percent of the observed asbestos structures were less than 5 µm in length. Of the 127 asbestos fibers observed, none were greater than 5 µm in length.

TABLE B-49. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE H

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	20	100	0	35	10	5	50
	1990	0	-	-	-	-	-	-
	1991	7	100	0	57.1	14.3	14.3	14.3
	1992	10	100	0	90	0	0	10
Perimeter area	1988	76	100	0	81.6	2.6	0	15.8
	1990	0	-	-	-	-	-	-
	1991	10	100	0	80	0	0	20
	1992	47	100	0	59.6	12.8	2.1	25.5
Outdoors	1988	4	100	0	75	0	0	25
	1990	0	-	-	-	-	-	-
	1991	5	100	0	80	0	0	20
	1992	2	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-50. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE H

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	20	40	70	80	90	90	95
	1990	0	-	-	-	-	-	-
	1991	7	57.1	85.7	100	100	100	100
	1992	10	80	90	100	100	100	100
Perimeter area	1988	76	59.2	94.7	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	10	70	80	90	100	100	100
	1992	47	61.7	83	85.1	85.1	93.6	97.9
Outdoors	1988	4	25	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	5	100	100	100	100	100	100
	1992	2	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Followup Air Monitoring - August 1991

The average airborne asbestos concentrations in the previously abated area and the perimeter area in May 1991 exceeded 0.02 s/cm^3. Therefore, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 15, 1991. The average airborne asbestos concentration in the previously abated area (0.035 s/cm^3) exceeded 0.02 s/cm^3; therefore, NJDOH directed the school to initiate a response action to reduce the airborne asbestos concentrations in this area. The school subsequently employed an asbestos abatement contractor to clean the previously abated and perimeter areas. When the cleaning action was complete, EPA/NJDOH conducted followup air monitoring on August 29, 1991, to determine the residual levels of airborne asbestos. The average airborne asbestos concentrations in the previously abated area and in the perimeter area were below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

Followup Air Monitoring - August 1992

Because the average airborne asbestos concentration in the perimeter area (0.025 s/cm^3) in May 1992 exceeded 0.02 s/cm^3, NJDOH-EHS required a response action at this school. The school subsequently used in-house staff to clean the previously abated and perimeter areas. When the cleaning action was complete, EPA/NJDOH conducted followup air monitoring in August 1992 to determine the residual levels of airborne asbestos. The average airborne asbestos concentration in the previously abated area (0.02 s/cm^3) and perimeter area (0.015 s/cm^3) did not exceed 0.02 s/cm^3; therefore, no further monitoring activity was required at this school.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site H as part of the State's traditional quality assurance program which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Two visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on heating units, on pipes in the hallways and classrooms, on electrical wires and outlet boxes, at floor-wall corners, and around air vents. The contractor was required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection, which the site passed.

1991 Inspection

On August 16, 1991, NJDOH conducted a visual inspection at Site H to determine potential sources of airborne asbestos measured by EPA/NJDOH in April 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas of the 1988 abatement indicated in the following subsections were examined.

1988 Abatement Areas

Corridor by the Shop Areas--Spray-applied ceiling debris collected from the top surface of the ceiling access panels contained 7 percent chrysotile asbestos (Table B-51). As indicated in the table, an accumulation of dust found on the baseboard heating pipes tested positive for asbestos, and the TSI on pipes above the ceiling did not contain asbestos.

Corridor to the Gymnasium--The TSI on pipes above the ceiling did not contain asbestos (Table B-51).

Mechanical Arts Shops--Metal partition walls along the windows contained ceiling debris (8 percent chrysotile) and dust that tested positive for asbestos (Table B-51). Radiators were also found to contain debris and dust that tested positive for chrysotile asbestos.

1988 Perimeter Areas

Hallway by the Custodian's Locker Room--Duct insulation above the ceiling in the hallway outside the men's custodian locker room was friable and contained 1 percent chrysotile and 6 percent amosite asbestos (Table B-51). The duct insulation was not included in the Asbestos Management Plan.

Auditorium--A fireproofing type of material adhered to several areas of the stage wall. Two samples of this material contained 27 and 35 percent chrysotile asbestos (Table B-51).

Conclusions

The asbestos-containing debris and dust on ceiling panels and behind partition walls were a potential source of airborne asbestos fibers measured in May 1991. This debris was from improper O&M activities or from uninventoried or residual ACM from the 1988 abatement. No asbestos-containing duct insulation was identified in the Asbestos Management Plan. The Asbestos Management Plan also erroneously identified the TSI on pipes above the corridor ceilings as asbestos-containing material.

Because the Asbestos Management Plan was in error, the potential exists for the disturbance of unidentified ACM.

TABLE B-51. SUMMARY OF BULK SAMPLE RESULTS–SITE H 1991 INSPECTION

Location	Type of material	Analyses
<u>1988 Abatement Area</u>		
Drafting storage	Block pipe insulation debris	Negative
Hall at shops	Above suspended ceiling, 4-in. block pipe insulation	Negative
Hall at shops	Above suspended ceiling, elbow debris with dark spots	Negative
Hall at shops	Above suspended ceiling, 7-in. block pipe insulation with straw	Negative
Hall to gymnasium	Above suspended ceiling, elbow with dark spots	Negative
Hall to gymnasium	Above suspended ceiling, block pipe insulation with straw	Negative
Hall at shops	Radiator dust	Positive[a], chrysotile asbestos
Hall intersection (shop-cafe), access panel	Residual ceiling material	7% chrysotile asbestos
End shop, partition wall	Dust and debris	Positive, chrysotile asbestos
Drafting shop, partition wall	Ceiling debris	8% chrysotile asbestos
Drafting shop	Radiator dust	Positive, chrysotile asbestos
<u>1988 Perimeter Area</u>		
Hall at Custodian's office	Duct insulation	1% chrysotile asbestos 6% amosite asbestos
Auditorium stage, wall at electrical panel	Debris	35% chrysotile asbestos
Auditorium stage, by duct	Debris	27% chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

SITE I

Background

Site Description

The abatement project at this single-story school building involved the removal of approximately 5100 ft^2 of spray-applied, asbestos-containing, acoustical ceiling plaster. The abatement area included an office, a lobby, and an auditorium. The project specifications indicated that the asbestos content of the ceiling plaster was approximately 5 to 25 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-52 summarizes the results from the four sampling efforts. Figure B-9 shows the mean airborne asbestos concentrations at Site I. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-53 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-52. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE I[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0	0	0	0	0	0	0.005	0	0.020
Simulated occupancy- 1990	0.001	0	0.005	0.011	0	0.056	0.001	0	0.005
Occupied conditions- 1991	0.003	0	0.007	0.005	0	0.011	0.005	0	0.020
Occupied conditions- 1992	0.001	0	0.002	0.001	0	0.003	0.002	0	0.009

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-53. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE I

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0389	O(0.005) A(0) P(0)
Simulated occupancy-1990	0.7400	P(0.011) A(0.001) O(0.001)
Occupied conditions-1991	0.6961	P(0.005) O(0.005) A(0.003)
Occupied conditions-1992	0.4809	O(0.002) A(0.001) P(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

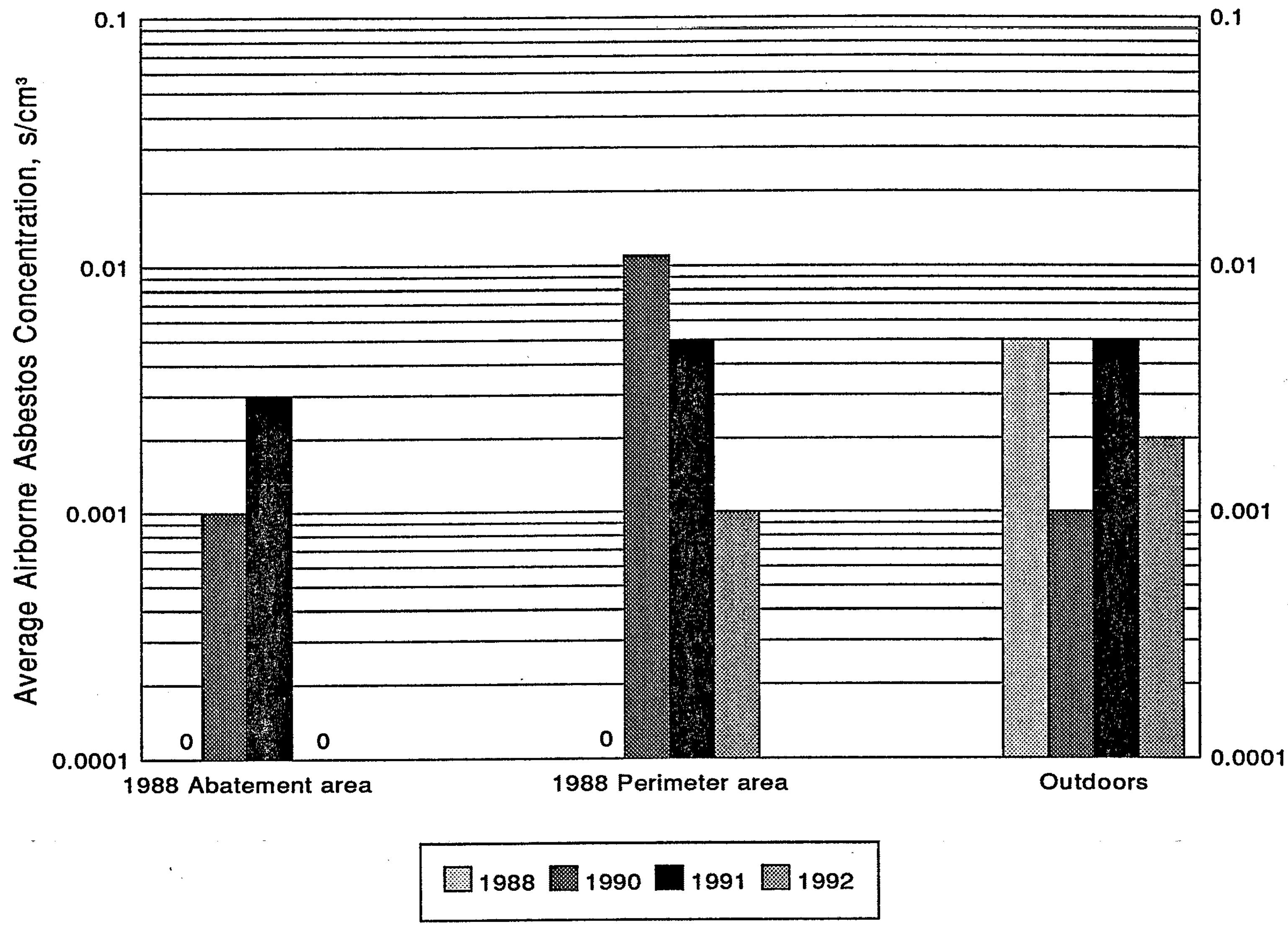

Figure B-9. Average airborne asbestos concentrations measured at Site I.

Summary of Air Monitoring Results

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (0 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.005 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.005 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.011 s/cm^3) was not significantly different from the average outdoor concentration (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.011 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.005 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.005 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.005 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-54 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-54. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE I

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.1141	1991(0.003) 1992(0.001) 1990(0.001) 1988(0)
Perimeter area	0.2019	1990(0.011) 1991(0.005) 1992(0.001) 1988(0)
Outdoors	0.6690	1988(0.005) 1991(0.005) 1992(0.002) 1990(0.001)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

Differences between average levels measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.003 s/cm^3) and the highest individual concentration (0.007 s/cm^3) were measured during occupied conditions in 1991, 3 years after the 1988 abatement.

Perimeter

Differences between average levels measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average (0.011 s/cm^3) and highest individual (0.056 s/cm^3) concentrations were measured during simulated occupancy, 2 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.005 s/cm^3) and the highest individual concentration (0.020 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement and during occupied conditions in 1991, 3 years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-55 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 43 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (88.4 percent), and to a lesser extent, matrices (11.6 percent). Table B-56 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. All of the observed asbestos structures were less than 5 μm in length.

NJDOH Visual Inspection

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site I as part of the State's traditional quality assurance program which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

TABLE B-55. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE I

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	0	-	-	-	-	-	-
	1990	1	100	0	100	0	0	0
	1991	4	100	0	75	0	0	25
	1992	1	100	0	100	0	0	0
Perimeter area	1988	0	-	-	-	-	-	-
	1990	11	100	0	100	0	0	0
	1991	7	100	0	100	0	0	0
	1992	1	100	0	0	0	0	100
Outdoors	1988	7	100	0	100	0	0	0
	1990	1	100	0	100	0	0	0
	1991	6	100	0	83.3	0	0	16.7
	1992	4	100	0	50	0	0	50

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-56. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE I

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 μm	≤2 μm	≤3 μm	≤4 μm	≤5 μm	≤10 μm
Abatement area	1988	0	-	-	-	-	-	-
	1990	1	100	100	100	100	100	100
	1991	4	100	100	100	100	100	100
	1992	1	0	100	100	100	100	100
Perimeter area	1988	0	-	-	-	-	-	-
	1990	11	54.5	100	100	100	100	100
	1991	7	42.9	100	100	100	100	100
	1992	1	0	0	100	100	100	100
Outdoors	1988	7	57.1	85.7	100	100	100	100
	1990	1	0	0	0	0	100	100
	1991	6	66.7	100	100	100	100	100
	1992	4	50	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Four visual inspections were required at this site. The site failed the first visual inspection because of the presence of residual materials or loose granular debris on corkboards and walls, on tops of wood partitions under the stage, on light fixtures and electrical cords, at ceiling-wall junctions, and on the carpeted area around the stage. The contractor was required to reclean these areas. After the affected areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of debris at ceiling-wall junctions, above the entry doorway, on electrical wires, and on corkboards. The contractor was again required to reclean the affected areas. After the areas were recleaned, NJDOH conducted a third visual inspection. The site failed the third visual inspection because of the presence of debris at ceiling-wall junctions and on the floor. After these areas were recleaned, NJDOH conducted a fourth visual inspection, which the site passed.

1991 Inspection

Although monitoring conducted in May 1991 found airborne asbestos levels within the AHERA criterion, on October 30, 1991, NJDOH conducted a visual inspection at Site I as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in October 1991.

1988 Abatement Areas

Entry Lobby and Athletic Office--Dust from one sample on top of the trophy cabinet and inside the radiator at the east window wall tested positive for chrysotile asbestos (Table B-57).

Auditorium--Unsecured scaffolding limited the inspection, and extension ladders were not available. No debris was noted.

1988 Perimeter Areas

Corridors--Thermal system insulation was noted above the suspended ceilings of the corridors. It appeared to be in generally good condition.

Library Office--Residue from the ceiling abatement was found on the window soffit. This material tested positive for chrysotile asbestos (Table B-57).

Library Air-Handling Room--Thermal system insulation debris (2 to 5 percent chrysotile asbestos) was found on the floors and the upper surfaces of the air-handling units (Table B-57).

Conclusions

Residual asbestos-containing dust was noted on horizontal surfaces in several areas of the 1988 abatement area and perimeter areas.

TABLE B-57. SUMMARY OF BULK SAMPLE RESULTS -- SITE I 1991 INSPECTION

Location	Type of Material	Analyses
<u>1988 Abatement Area</u>		
Entry lobby	Dust, top of trophy cabinet, east side (wipe sample)	Negative
Entry lobby	Dust, top of trophy cabinet, east side (wipe sample)	Positive[a], chrysotile asbestos
Entry lobby	Dust inside east radiator (wipe sample)	Positive, chrysotile asbestos
<u>1988 Perimeter Areas</u>		
Library, office	Residue, window soffit	Positive, chrysotile asbestos
Library, air-handling room	Elbow debris on floor	Positive, chrysotile asbestos
Library, air-handling room	Top air unit, elbow debris	2% Chrysotile asbestos
Library, air-handling room	Debris, top of east unit	5% Chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

SITE J

Background

Site Description

The abatement project at this two-story school building involved the removal of approximately 5300 ft^2 of spray-applied asbestos-containing fireproofing from structural steel and metal ceiling decks. The abatement area included two electrical transformer vaults and two mechanical equipment rooms. The project specifications indicated that the asbestos content of the cementitious fireproofing was approximately 10 to 25 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-58 summarizes the results from the four sampling efforts. Figure B-10 shows the mean airborne asbestos concentrations at Site J. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-59 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-58. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE J[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.004	0.004	0.004	0.001	0	0.004	0.001	0	0.004
Simulated occupancy- 1990	0	0	0	0.003	0	0.005	0	0	0
Occupied conditions-1991	0.003	0	0.011	0	0	0	0.001	0	0.004
Occupied conditions-1992	0.003	0	0.005	0.012	0	0.055	0.001	0	0.003

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-59. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE J

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0086	A(0.004) <u>P(0.001) O(0.001)</u>
Simulated occupancy-1990	0.0156	P(0.003) <u>A(0) O(0)</u>
Occupied conditions-1991	0.2878	<u>A(0.003) O(0.001) P(0)</u>
Occupied conditions-1992	0.5921	<u>P(0.012) A(0.003) O(0.001)</u>

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

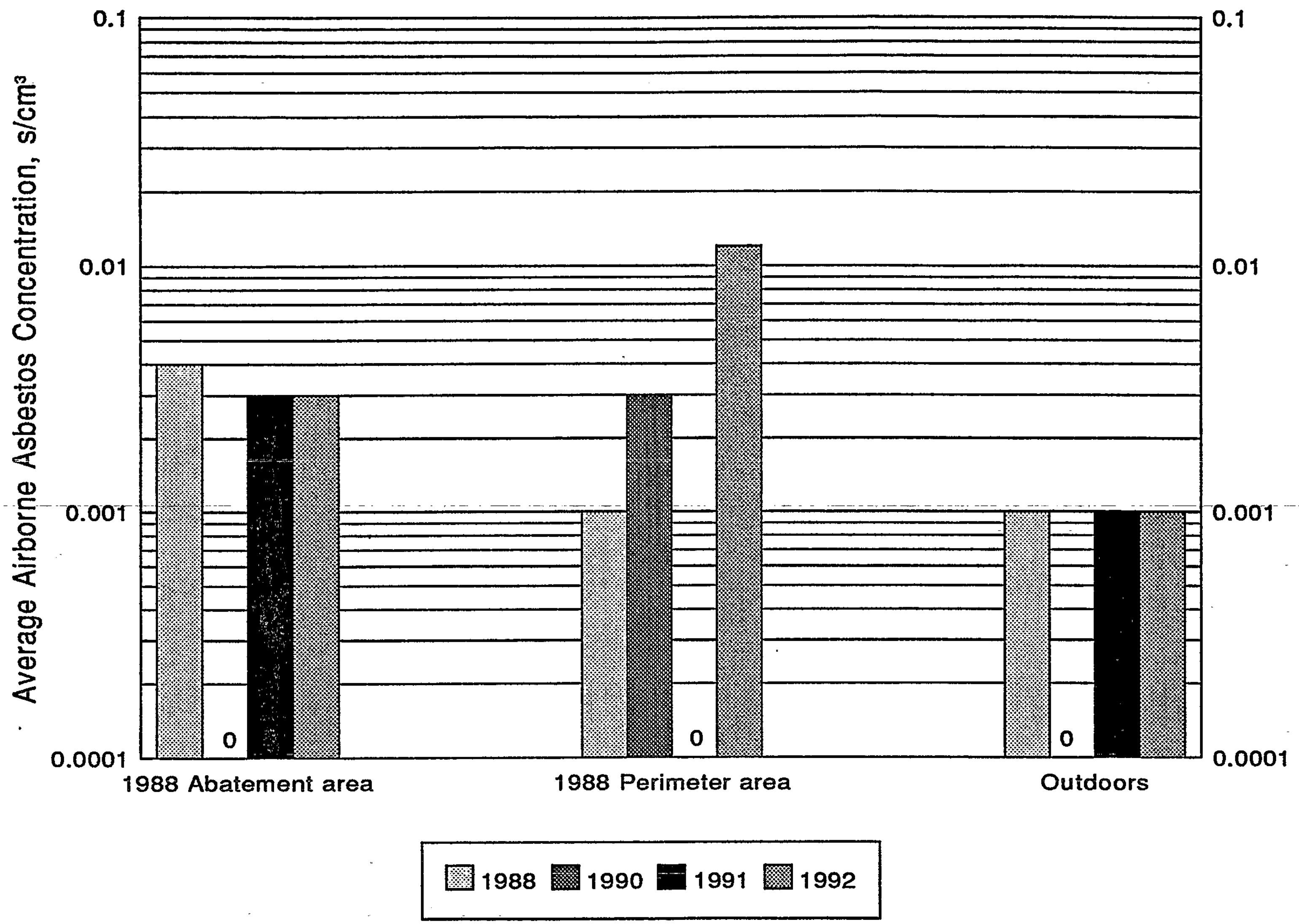

Figure B-10. Average airborne asbestos concentrations measured at Site J.

Summary of Air Monitoring Results

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (27 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.004 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.004 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.001 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.003 s/cm^3) was significantly greater than the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured in the perimeter areas (0.003 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.012 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.012 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-60 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-60. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE J

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0219	1988(0.004) 1991(0.003) 1992(0.003) 1990(0)
Perimeter area	0.2544	1992(0.012) 1990(0.003) 1988(0.001) 1991(0)
Outdoors	0.6112	1988(0.001) 1991(0.001) 1992(0.001) 1990(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

Differences between average levels measured in 1988, 1990, 1991, and 1992 were not statistically significant except that the average concentration measured during simulated occupancy in 1990 was significantly less than that measured during the AHERA clearance phase of the 1988 abatement. The highest average concentration (0.004 s/cm^3) was measured during the AHERA clearance phase of the 1988 abatement, and the highest individual concentration (0.011 s/cm^3) was measured during occupied conditions in 1991, three years after the 1988 abatement.

Perimeter

Differences between average levels measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average (0.012 s/cm^3) and highest individual (0.055 s/cm^3) concentrations were measured during occupied conditions, 4 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentrations (0.001 s/cm^3) were measured in 1988, 1991, and 1992 and the highest individual concentrations (0.004 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement and during occupied conditions in 1991, three years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-61 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 46 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (78.3 percent), and to a lesser extent, clusters (10.9 percent), matrices (11.6 percent), and bundles (4.3 percent).

Table B-62 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 97.8 percent of the observed asbestos structures were less than 5 µm in length. Of the 36 asbestos fibers observed, none was greater than 5 µm in length.

TABLE B-61. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE J

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	5	100	0	20	0	40	40
	1990	0	-	-	-	-	-	-
	1991	4	100	0	100	0	0	0
	1992	6	100	0	83.3	0	0	16.7
Perimeter area	1988	1	100	0	100	0	0	0
	1990	3	100	0	66.7	0	33.3	0
	1991	0	-	-	-	-	-	-
	1992	23	100	0	82.6	8.7	8.7	0
Outdoors	1988	1	100	0	100	0	0	0
	1990	0	-	-	-	-	-	-
	1991	1	100	0	100	0	0	0
	1992	2	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-62. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE J

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	5	40	60	80	100	100	100
	1990	0	-	-	-	-	-	-
	1991	4	50	100	100	100	100	100
	1992	6	66.7	83.3	100	100	100	100
Perimeter area	1988	1	100	100	100	100	100	100
	1990	3	66.7	66.7	66.7	66.7	66.7	100
	1991	0	-	-	-	-	-	-
	1992	23	47.8	87	95.7	100	100	100
Outdoors	1988	1	100	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	1	100	100	100	100	100	100
	1992	2	50	50	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

NJDOH Visual Inspection

1988 Inspection

The NJDOH did not perform a visual inspection at this site. Upon completion of the final cleaning, the abatement contractor requested that a visual inspection be conducted by the onsite AST, who was the building owner's representative. The AST conducted the visual inspection within 2 hours after notification and did not identify any areas that required further cleaning.

1991 Inspection

Although monitoring conducted in May 1991 found airborne asbestos levels within the AHERA criterion, on November 8, 1991, a NJDOH Visual Inspection was conducted at Site J as a follow-up. This facility did not have an AHERA Management Plan and being a college is not required to do so. The visual inspection strategy considered the asbestos abatement history of the site, the operations and maintenance (O&M) activities, and other sources of possible asbestos contamination. Only those areas indicated in the following subsections were examined by the NJDOH inspector in November 1991.

1988 Abatement Areas

Mechanical Room--This area contains the air-handling and electrical equipment for the building. The main room is dominated by the ductwork and blower units of the HVAC system. Non-asbestos spray-on replacement material had been applied to the abated surfaces. The replacement materials and the accompanying debris from their application made it difficult to detect debris or residual material from the original asbestos application.

It appears that the fiberglass pipe insulation with cementitious joint and elbow compounds were not removed during the 1988 abatement. Debris was noted in all areas examined. Also, the repairs made to the materials have rendered a high number of homogeneous "types." These materials were not sampled because the facility assumes they are asbestos.

The top of the ducts, wall and ceiling surfaces, mechanical support stands and brackets, floor drains, and the electrical equipment all showed contamination [5 to 19 percent chrysotile asbestos (Table B-63)]. The areas from which bulk samples were collected were probably covered with polyethylene sheeting during the 1988 abatement, and were not accessible for a visual inspection prior to air sampling.

TABLE B-63. SUMMARY OF BULK SAMPLE RESULTS -- SITE J 1991 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Area		
Mechanical room	Residue behind ducting	9% chrysotile asbestos
Mechanical room	Spray-on debris on wall at "Dover" box	Positive[a], chrysotile asbestos
Mechanical room	Spray-on debris top of duct, filter entry	5% chrysotile asbestos
Mechanical room	Floor drain, spray-on debris	Positive, chrysotile asbestos
Mechanical room	Spray-on debris, "Alpha" tank supports	Positive, chrysotile asbestos
Mechanical room	Spray-on debris under main filter duct	19% chrysotile asbestos
Mechanical room	Spray-on debris in floor trap	Negative
Mechanical room	Southwest corner, spray-on debris on floor	Positive, chrysotile asbestos
Mechanical room	Debris in hangers	Negative
Mechanical room	Wall at entry door, smudge of spray-on, on wall	Positive, chrysotile asbestos
Mechanical room	New sealant at duct	Negative
1988 Perimeter Area		
Hallway at mechanical room entry	Spray-on debris above drop ceiling	13% chrysotile asbestos
Hallway at elevator	Spray-on debris above drop ceiling	7% chrysotile asbestos
Hallway at slate foyer	Overspray above drop ceiling	16% chrysotile asbestos
Hallway at school store	Spray-on debris above ceiling tile	7% chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

1988 Perimeter Areas

Hallway at Mechanical Room Entrance--The cementitious joints and elbows associated with the fiberglass pipe insulation were noted in the area above the dropped ceiling. All of these materials appeared to be in good condition.

The areas below several pipe and duct penetrations in the wall have become contaminated during abatement or repair actions (7 to 16 percent chrysotile asbestos). Thick slabs and pieces of spray-on debris from the mechanical room are lying on the upper surface of the dropped ceiling system by the elevator, by the mechanical room entrance, and in the area by the slate foyer. The game room and other areas were not accessed for inspection because of student occupancy and equipment storage. Overspray was also noted in these perimeter areas on the beams, block walls, and ductwork.

Conclusions

As noted earlier, debris was found in areas that may have been covered by polyethylene sheeting during clearance air sampling or in areas that were outside the abatement zone (above dropped ceilings). Clearance and followup testing would not have disturbed such material. Also, much of the asbestos residue and debris has been covered by replacement material.

Most debris was located on top of and under ducts or in other inaccessible areas. This material might not be disturbed by floor-level aggressive sampling or daily operations. Free fibers may have been scavenged from remaining material over time and exhausted by the ventilation system in these areas.

SITE K

Background

Site Description

During the summer of 1988, asbestos-containing acoustical ceiling plaster was removed from Sites K and N. Site K involved removal of approximately 8200 ft^2 of spray-applied acoustical plaster from an "egg crate design" concrete ceiling. The abatement area included the carpentry shop, mechanical arts classrooms, and offices. The acoustical plaster contained 10 to 25 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

During the summer of 1991, 75,600 square feet of asbestos-containing ceiling plaster was abated. No other abatement activity occurred between 1988 and 1992.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area, and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-64 summarizes the results from the four sampling efforts. Figure B-11 shows the mean airborne asbestos concentrations at Site K. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-65 presents the results of the ANOVA analysis. The subsections following the tables summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-64. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE K[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.063	0.035	0.103	0.008	0	0.015	0	0	0
Simulated occupancy- 1990	0	0	0	0.007	0.005	0.010	0.001	0	0.005
Occupied conditions-1991	0.041	0.014	0.097	0.003	0	0.007	0	0	0
Occupied conditions-1992	0.007	0	0.017	0.002	0	0.005	0.004	0	0.012

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-65. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE K

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0001	A(0.063) P(0.008) O(0)
Simulated occupancy-1990	0.0059	P(0.007) <u>O(0.001) A(0)</u>
Occupied conditions-1991	0.0001	A(0.041) <u>P(0.003) O(0)</u>
Occupied conditions-1992	0.3567	<u>A(0.007) O(0.004) P(0.002)</u>

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

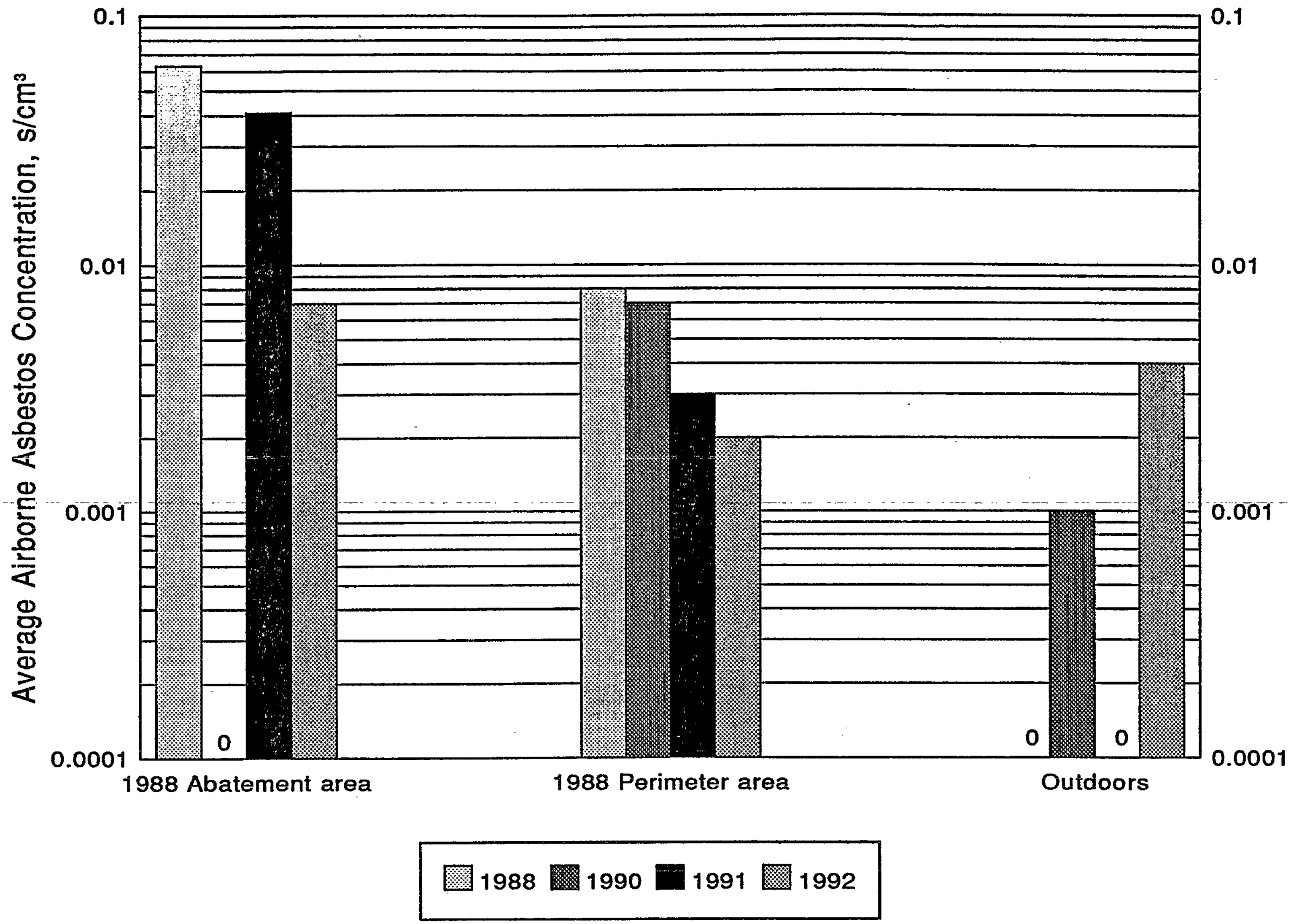

Figure B-11. Average airborne asbestos concentrations measured at Site K.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured during the AHERA clearance phase of the 1988 abatement by EPA/NJDOH showed that this site would have failed the AHERA initial screening test because the average filter concentration (431 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.063 s/cm^3) was significantly greater than the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.008 s/cm^3) was significantly greater than the average concentration measured outdoors (0 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.063 s/cm^3) was significantly greater than the average concentration measured in the perimeter area (0.008 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.007 s/cm^3) was significantly greater than the average outdoor concentration (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured in the perimeter area (0.007 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.041 s/cm^3) was significantly less than the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.041 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.003 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.002 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-66 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-66. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE K

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0001	1988(0.063) 1991(0.041) 1992(0.007) 1990(0)
Perimeter area	0.3674	1988(0.008) 1990(0.007) 1991(0.003) 1992(0.002)
Outdoors	0.2137	1992(0.004) 1990(0.001) 1988(0) 1991(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

The average airborne asbestos concentrations measure during the AHERA clearance phase of the 1988 abatement (0.063 s/cm^3) and during occupied conditions in 1991 (0.041 s/cm^3) were not significantly different, but they were significantly greater than the average concentrations measured during simulated occupancy in 1990 (0 s/cm^3) and during occupied conditions in 1992 (0.007 s/cm^3). Furthermore, the average concentration measured in 1992 was significantly greater than the average concentration measured in 1990. The highest average concentration and the highest individual concentration were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter

Differences between average levels measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average (0.008 s/cm^3) and highest individual (0.015 s/cm^3) concentrations were measured during the AHERA clearance phase of the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.004 s/cm^3) and the highest individual concentration (0.012 s/cm^3) were measured during occupied conditions in 1992, four years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-67 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 169 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (84.6 percent), and to a lesser extent, matrices (10.7 percent), clusters (3.0 percent), and bundles (1.8 percent).

Table B-68 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 97.6 percent of the observed asbestos structures were less than 5 µm in length. Of the 143 asbestos fibers observed, only 1 (0.7 percent) was greater than 5 µm in length.

TABLE B-67. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE K

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	81	100	0	81.5	2.5	3.7	12.3
	1990	0	-	-	-	-	-	-
	1991	44	100	0	90.9	0	0	9.1
	1992	12	100	0	83.3	0	0	16.7
Perimeter area	1988	10	100	0	100	0	0	0
	1990	7	100	0	57.1	0	28.6	14.3
	1991	5	100	0	100	0	0	0
	1992	4	100	0	50	25	0	25
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	6	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-68. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE K

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	81	53.1	91.4	95.1	95.1	95.1	100
	1990	0	-	-	-	-	-	-
	1991	44	68.2	95.5	100	100	100	100
	1992	12	75	91.7	91.7	91.7	100	100
Perimeter area	1988	10	90	100	100	100	100	100
	1990	7	42.9	71.4	85.7	100	100	100
	1991	5	100	100	100	100	100	100
	1992	4	50	75	75	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	6	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Followup Air Monitoring - August 1991

Because the average airborne asbestos concentration in the previously abated area (0.041 s/cm^3) exceeded 0.02 s/cm^3 in April 1991, EPA/NJDOH conducted follow-up monitoring under simulated occupancy conditions on August 14, 1991, to determine whether airborne asbestos was still present at levels similar to those measured in April 1991. The August 14 results revealed that the average airborne asbestos concentrations in the previously abated area and in the perimeter area were below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site K as part of the State's traditional quality assurance program which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Four visual inspections were required at this site. The site failed the first visual inspection because of the presence of gross debris on the concrete substrate surfaces, under pipe hangers, on vertical and horizontal surfaces, and on the scaffolding equipment. The contractor was then required to reclean the affected areas. After the areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of gross debris found behind immovable wooden shelves, at floor-wall junctions, behind student lockers, on horizontal surfaces, and on other immovable objects. The contractor was again required to reclean the affected areas. After the areas were recleaned, NJDOH conducted a third visual inspection. The site failed the third visual inspection because of gross debris on horizontal surfaces, behind immovable objects, and at floor-wall junctions. After the affected areas were recleaned, NJDOH conducted a fourth visual inspection, which the site passed.

1991 Inspection

On August 15, 1991, an NJDOH visual inspection was conducted at Sites K and N as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined.

1988 Abatement Areas

Carpentry Shop and Classroom--The surface dust found on building and equipment surfaces tested positive for asbestos (Table B-69). Floor tile from the carpentry classroom contained 7 percent chrysotile. The floor tile was not identified as ACM in the Asbestos Management Plan.

1988 Perimeter Areas

Hallway and Miscellaneous Classrooms--Samples of building materials found in these areas did not show detectable levels of asbestos.

Conclusions

Asbestos-containing dust was present on surfaces in the carpentry shop. Asbestos materials in the brake and clutch assemblies in various high speed equipment could be a possible source of the elevated asbestos levels in the 1988 abatement area. The misidentification of vinyl asbestos-containing floor tile (VAT) in the Asbestos Management Plan could also lead to uncontained VAT removals, improper O&M, and possible contamination.

TABLE B-69. SUMMARY OF BULK SAMPLE RESULTS SITE K 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
Dust samples:		
Carpentry loft	Duct grill	Negative
Carpentry shop	North Nesbitt heater	Positive[a], amosite asbestos Positive, chrysotile asbestos
Carpentry shop	South Nesbitt heater	Positive, chrysotile asbestos
Carpentry shop	Table saw motor box	Positive, chrysotile asbestos
Carpentry shop	Window ledge, north	Positive, chrysotile asbestos Positive, amosite asbestos
Carpentry shop	Window ledge, north	Positive, chrysotile asbestos Positive, amosite asbestos
Bulk samples:		
Carpentry shop	Spray-on ceiling material	Negative
Carpentry classroom	Dust, top of ceiling	Negative
Carpentry shop	Roofing felt	Negative
Carpentry shop	Spray flakes, window ledge	Negative
Carpentry shop	Roof shingles (display)	Negative
Carpentry shop	Ceiling tile	Negative
Carpentry shop classroom	Floor tile	7% Chrysotile asbestos
Carpentry shop	Sheetrock (display)	Trace[b], chrysotile asbestos
1988 Perimeter Area		
Hall outside carpentry shop	Ceiling tile	Negative
Special education	Sheetrock (stored)	Negative
Exterior storage	Mason's stand	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

[b] Trace = <1 percent asbestos.

SITE L

Background

Site Description

The abatement project at this single-story school building involved the removal of approximately 1600 ft^2 of trowel-applied, asbestos-containing, acoustical ceiling plaster. The abatement area was an auditorium. The project specifications indicated that the asbestos content of the ceiling plaster was approximately 15 to 25 percent. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area, but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-70 summarizes the results from the four sampling efforts. Figure B-12 shows the mean airborne asbestos concentrations at Site L. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-71 presents the results of the ANOVA analysis. The subsections following the tables summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (768 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test

TABLE B-70. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE L[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.118	0.093	0.156	0.060	0.026	0.181	0.004	0	0.015
Simulated occupancy- 1990	0.002	0	0.010	0.001	0	0.005	0	0	0
Occupied conditions-1991	0.006	0	0.016	0.003	0	0.006	0	0	0
Occupied conditions-1992	0.003	0	0.007	0.002	0	0.005	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-71. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE L

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0001	A(0.118) P(0.060) O(0.004)
Simulated occupancy-1990	0.6016	A(0.002) P(0.001) O(0)
Occupied conditions-1991	0.0752	A(0.006) P(0.003) O(0)
Occupied conditions-1992	0.0408	A(0.003) P(0.002) O(0)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

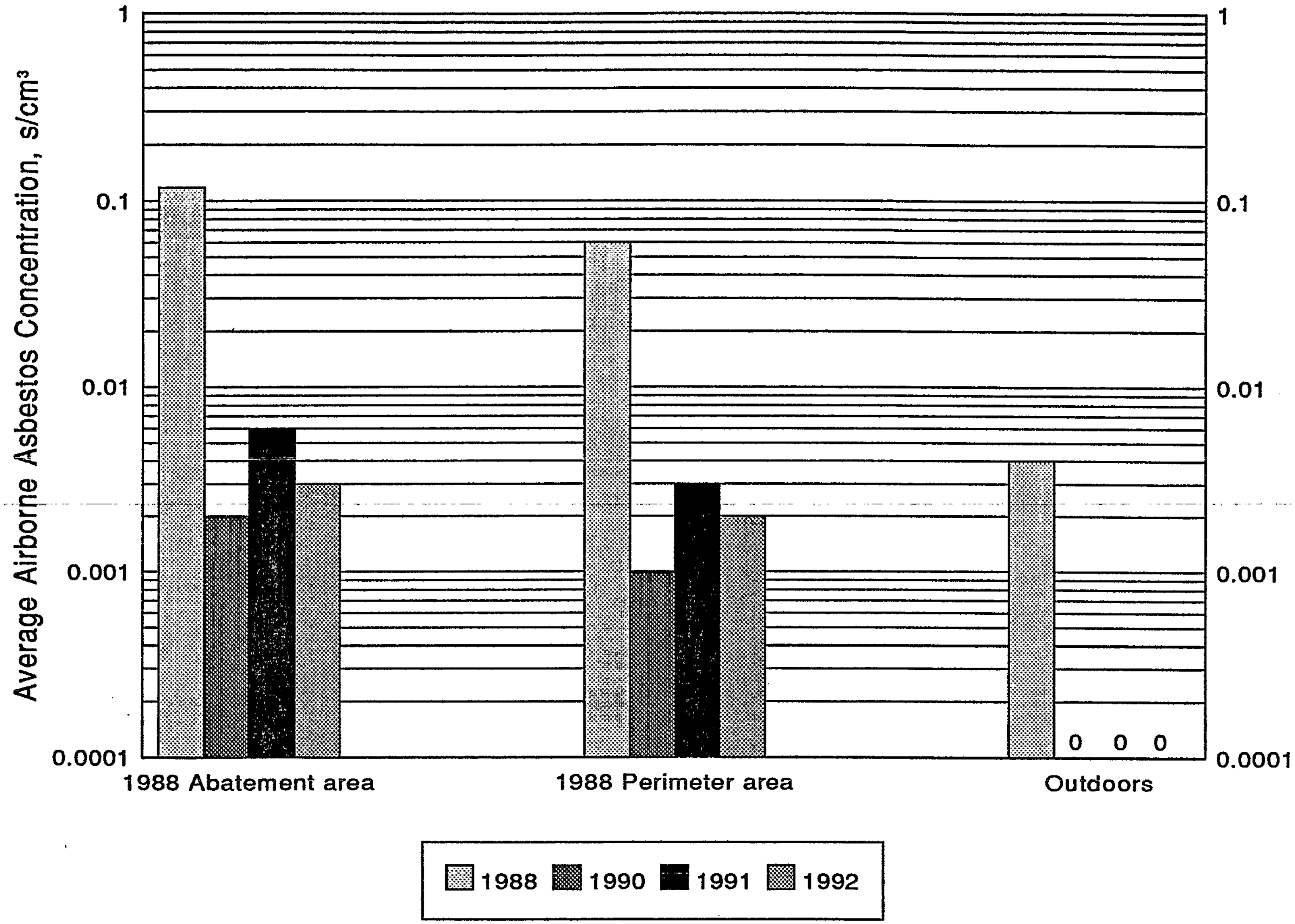

Figure B-12. Average airborne asbestos concentrations measured at Site L.

regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.118 s/cm^3) was significantly greater than the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.060 s/cm^3) was significantly greater than the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.118 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.060 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.001 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.002 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.006 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.006 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.003 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.002 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately.

Table B-72 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-72. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE L

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0001	1988(0.118) 1991(0.006) 1992(0.003) 1990(0.002)
Perimeter area	0.0001	1988(0.060) 1991(0.003) 1992(0.002) 1990(0.001)
Outdoors	0.1191	1988(0.004) 1990(0) 1991(0) 1992(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

The average airborne asbestos concentrations measure during the AHERA clearance phase of the 1988 abatement (0.118 s/cm^3) was significantly greater than the average concentration measured during simulated occupancy in 1990 (0.002 s/cm^3) and during occupied conditions in 1991 (0.006 s/cm^3) and 1992 (0.003 s/cm^3). Differences between average airborne asbestos concentrations measured in 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.118 s/cm^3) and the highest individual concentration (0.156 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter

The average airborne asbestos concentration measured during the AHERA clearance phase of the 1988 abatement (0.060 s/cm^3) was significantly greater than the average concentrations measured during simulated occupancy in 1990 (0.001 s/cm^3) and during occupied conditions in 1991 (0.003 s/cm^3) and 1992 (0.002 s/cm^3). Differences between average airborne asbestos concentrations measured in 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.060 s/cm^3) and the highest individual concentration (0.181 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.004 s/cm^3) and the highest individual concentration (0.015 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-73 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 273 asbestos structures, of which 99.6 percent were chrysotile asbestos and 0.4 percent were amphibole asbestos. Overall, the asbestos structures were primarily fibers (61.9 percent), and to a lesser extent, clusters (18.3 percent), matrices (14.3 percent), and bundles (5.5 percent).

Table B-74 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 93.0 percent of the observed asbestos structures were less than 5 μm in length. Of the 169 asbestos fibers observed, only 9 (5.4 percent) were greater than 5 μm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site L as part of the State's traditional quality assurance program which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

TABLE B-73. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE L

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	149	100	0	59.7	6	21.5	12.8
	1990	2	100	0	50	50	0	0
	1991	10	100	0	10	10	0	80
	1992	7	85.7	14.3	28.6	14.3	0	57.1
Perimeter area	1988	90	100	0	75.6	2.2	17.8	4.4
	1990	1	100	0	0	100	0	0
	1991	5	100	0	0	0	20	80
	1992	4	100	0	75	0	25	0
Outdoors	1988	5	100	0	100	0	0	0
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	0	-	-	-	-	-	-

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-74. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE L

Sampling location	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	149	28.9	64.4	75.2	85.2	91.9	98.7
	1990	2	50	50	100	100	100	100
	1991	10	80	100	100	100	100	100
	1992	7	42.9	71.4	71.4	71.4	71.4	100
Perimeter area	1988	90	51.1	82.2	91.1	93.3	96.7	97.8
	1990	1	0	0	0	0	0	0
	1991	5	40	80	80	80	80	100
	1992	4	75	75	75	75	100	100
Outdoors	1988	5	100	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	0	-	-	-	-	-	-

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Two visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on the upper ledge of the auditorium ceiling and on the wooden blocks used to support the polyethylene containment barriers. The contractor was then required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection, which the site passed.

1991 Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, NJDOH conducted a visual inspection at Site L on October 24, 1991, as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated the following subsections were examined by the NJDOH inspector in October 1991.

1988 Abatement Areas

Auditorium--During the abatement of acoustical ceiling materials in the auditorium in 1988, scaffolding was used to access the materials, which were approximately 35 feet above the floor. The sloping floor prevented the use of conventional extension ladders to access the abatement zone. An attempt was made to access the overhead areas via an opening in the wall above the projection booth area; however, it was questionable whether the 1 ft-by-6 in. ductwork in this area or the plaster ceiling would support any weight. No catwalks were available to gain access to the truss/black-iron system to conduct an inspection for debris or overspray materials. Either some white "splotches" remained after abatement or they were splashes of encapsulant.

1988 Perimeter Areas

Stage--The Asbestos Management Plan does not list thermal system insulation in the stage area; however, the roof drain appears to be cementitious material that has sustained some minor damage from stored lumber (Table B-75).

Corridors--Thermal system insulation is present on pipe joints and elbows in the plenum above the corridor drop ceiling. The materials appear to have been disturbed. The Management Plan does not reflect this activity.

Conclusions

Inaccessibility to the abated areas prevented a definitive reinspection of the site.

TABLE B-75. SUMMARY OF BULK SAMPLE RESULTS - SITE L
1991 INSPECTION

Location	Type of Material	Analyses
Air handling loft, stage	Elbow, air unit	Negative
Air handling loft, stage	Elbow, air unit	Trace[a], chrysotile asbestos

[a] Trace = <1 percent asbestos.

SITE M

Background

Site Description

During the summer of 1988, two asbestos abatement projects were conducted at this school. Asbestos-containing thermal system insulation (TSI) was removed from a boiler, water tank, fan duct, and pipes in the boiler room located in the basement and from pipes in the corridor adjacent to the boiler room (Site C). TSI was removed from pipes in the corridors, classrooms, offices, storage rooms, and gymnasium located in the basement (Site M). The TSI contained approximately 40 to 60 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. There has been no additional abatement activity since 1988.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as the samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the abatement area and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST.

In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988.

In 1991 and 1992, air samples were collected at this school during actual occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-76 summarizes the results of the five sampling efforts. Figure B-13 illustrates the mean airborne asbestos concentrations at Site M. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-77. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-76. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE M[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors[b] (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	0.001	0	0.004	-[c]	-	-	0.003	0	0.011
Postabatement-1988	0.322	0.054	0.530	0.002	0	0.008	0.002	0	0.004
Simulated occupancy-1990	0	0	0	0	0	0	0	0	0
Occupied conditions-1991	0.023	0	0.056	0.004[d]	0	0.007	0.003	0	0
Occupied conditions-1992	0.003	0	0.005	0.005[d]	0	0.013	0.003	0	0.007

a Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

b Outdoor samples are the same as those collected at Site C in 1990, 1991, and 1992 (Site M was the second abatement project at this school in 1988).

c Preabatement samples were not collected in the perimeter areas.

d N=4.

TABLE B-77. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE M

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.4466	<u>O(0.003) A(0.001)</u>
Postabatement-1988	0.0001	A(0.322) <u>P(0.002) O(0.002)</u>
Simulated occupancy-1990	1.0	<u>A(0) P(0) O(0)</u>
Occupied conditions-1991	0.1924	<u>A(0.023) P(0.004) O(0.003)</u>
Occupied conditions-1992	0.8649	<u>P(0.005) A(0.003) O(0.003)</u>

a If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

b A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

c Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

d Sampling locations (means) connected by a line are not significantly different.

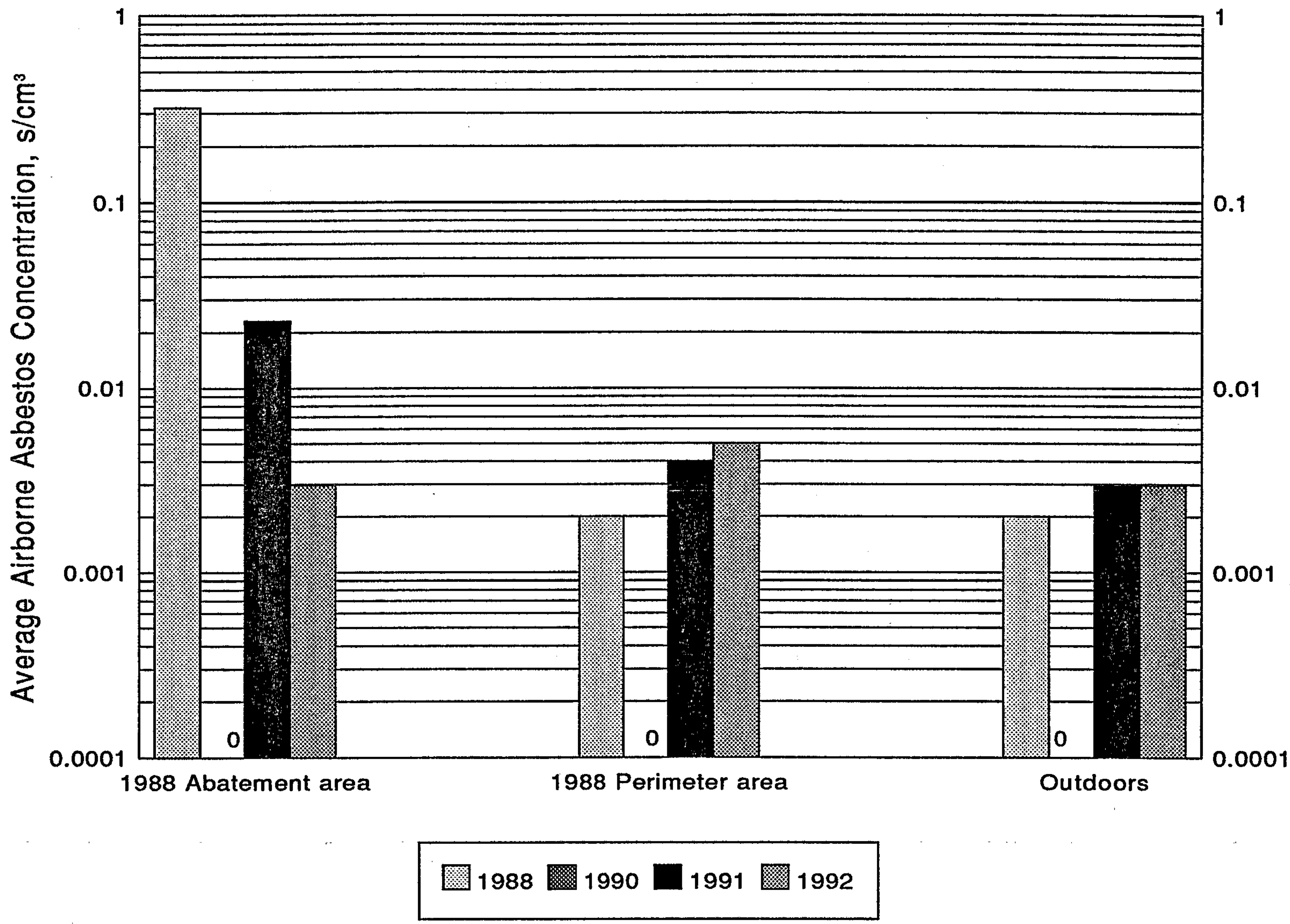

Figure B-13. Average airborne asbestos concentrations measured at Site M.

Preabatement - 1988

The average airborne asbestos concentration measured in the abatement area before the abatement (0.001 s/cm^3) was not significantly different from the average concentrations measured outdoors (0.003 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement by EPA/NJDOH showed that this site would have failed the AHERA initial screening test because the average filter concentration (2146 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.322 s/cm^3) was significantly greater than the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0.002 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.322 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.002 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.023 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.023 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.004 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.005 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-78 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

The average airborne asbestos concentrations measure during the AHERA clearance phase of the 1988 abatement (0.322 s/cm^3) was significantly greater than the average concentrations measured during simulated occupancy in 1990 (0 s/cm^3) and during occupied conditions in 1991 (0.023 s/cm^3) and in 1992 (0.003 s/cm^3). Differences between average airborne asbestos concentrations measured during occupied conditions in 1991 and 1992 were not statistically significant. Nor were the average concentrations measured in 1990 and 1992 statistically significant. The average concentration measured during occupied conditions in 1991 was, however, significantly greater than the average concentration measured during simulated occupancy in 1990. The highest average concentration (0.322 s/cm^3) and the highest individual concentration (0.530 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

TABLE B-78. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE M

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0001	1988(0.322) 1991(0.023) 1992(0.003) 1990(0)
Perimeter area	0.1487	1991(0.005) 1992(0.005) 1988(0.002) 1990(0)
Outdoors	0.2707	1991(0.003) 1992(0.003) 1988(0.002) 1990(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

Perimeter

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentrations (0.005 s/cm^3) was measured during occupied conditions in 1992 and the highest individual concentrations (0.013 s/cm^3) were measured during occupied conditions in 1992, 4 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.003 s/cm^3) and the highest individual concentrations (0.011 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-79 presents the distribution of structure type and morphology at each sampling location for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected

TABLE B-79. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE M

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	248	99.6	0.4	63.7	2.8	8.9	24.6
	1990	0	-	-	-	-	-	-
	1991	37	100	0	86.5	0	0	13.5
	1992	5	100	0	60	0	0	40
Perimeter area	1988	2	100	0	50	0	50	0
	1990	0	-	-	-	-	-	-
	1991	5	100	0	80	0	0	20
	1992	7	100	0	100	0	0	0
Outdoors[b]	1988	3	100	0	66.7	0	0	33.3
	1990	0	-	-	-	-	-	-
	1991	6	100	0	83.3	0	0	16.7
	1992	4	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Outdoor samples are the same as those collected at Site C in 1990, 1991, and 1992 (Site M was the second abatement project at this school in 1988).

outdoors yielded a total of 317 asbestos structures, of which 99.7 percent were chrysotile asbestos and 0.3 percent were amphibole asbestos. Overall, the asbestos structures were primarily fibers (68.1 percent), and to a lesser extent, matrices (22.4 percent), clusters (7.3 percent), and bundles (2.2 percent).

Table B-80 presents the cumulative size distribution of asbestos samples at each sampling location for each year of monitoring. Overall, 94.6 percent of the observed asbestos structures were less than 5 μm in length. Of the 216 asbestos fibers observed, only 7 (3.3 percent) was greater than 5 μm in length.

Followup Air Monitoring - August 1991

Because the May 1991 average airborne asbestos concentration in the previously abated area (0.023 s/cm^3) exceeded 0.02 s/cm^3, EPA/NJDOH conducted followup monitoring on August 13, 1991, under simulated occupancy conditions, to determine whether the airborne asbestos was still present at levels similar to those measured in May. The average airborne asbestos concentrations in the previously abated area (0.033 s/cm^3) still exceeded 0.02 s/cm^3; therefore, NJDOH directed the school to initiate a response action to reduce the airborne asbestos concentrations in the previously abated area. The school subsequently employed a licensed asbestos abatement contractor to clean these areas.

When the response action was complete, EPA/NJDOH conducted followup air monitoring on August 29, 1991, to determine the residual levels of airborne asbestos. Although the average airborne asbestos concentrations in the previously abated area (0.001 s/cm^3) was below 0.02 s/cm^3, the average concentration in the perimeter area (0.029 s/cm^3) exceeded 0.02 s/cm^3, therefore, NJDOH directed the school to reclean the perimeter areas. After the second response action NJDOH collected additional samples on September 3, 1991, in the previously abated area and the perimeter area. Average airborne asbestos concentrations in the previously abated area (0.005 s/cm^3, N=2) and the perimeter area (0 s/cm^3, N=8) were both below 0.02 s/cm^3; therefore, no further action was required at this site. Intervention continued, however, to resolve the elevated asbestos concentrations at this site.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site M as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

TABLE B-80. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE M

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	248	29.4	67.3	82.3	89.1	93.1	98
	1990	0	-	-	-	-	-	-
	1991	37	73	97.3	100	100	100	100
	1992	5	60	100	100	100	100	100
Perimeter area	1988	2	0	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	5	80	100	100	100	100	100
	1992	7	71.4	100	100	100	100	100
Outdoors[b]	1988	3	33.3	66.7	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	6	66.7	100	100	100	100	100
	1992	4	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Outdoor samples are the same as those collected at Site C in 1990, 1991, and 1992 (Site M was the second abatement project at this school in 1988).

Three visual inspections were required at this site. The site failed the first because debris was present on the floors and on pipe joints and elbows. The contractor was then required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because debris was found on pipes, on the floors and in wall penetrations. When these areas were recleaned, NJDOH conducted a third visual inspection and the site passed.

1991 Inspection

NJDOH conducted another visual inspection at Site M on August 14, 1991 to determine potential sources of airborne asbestos measured by EPA/NJDOH in May 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). In August 1991, the NJDOH inspector examined only those areas indicated in the following subsections.

1988 Abatement Areas

Classroom, Small Gymnasium, and Corridors

No TSI debris was found in these abatement areas. Plaster debris from the wall and ceiling surfaces was evident in many areas. Top-coat plaster from the recreation room and hallway did not test positive for asbestos; however, the browncoat underlay in the adjoining hallway showed trace amounts of chrysotile asbestos (Table B-81). The storage and office areas were locked and could not be accessed.

1988 Perimeter Area

Boiler Room--Miscellaneous debris mixed in with the coal tested positive for chrysotile (19 percent), amosite (3 percent), and crocidolite (trace) asbestos (Table B-81). The TSI debris mixed in with the coal tested positive for chrysotile asbestos. The TSI debris found under the boiler room stairway tested positive for chrysotile asbestos (67 percent).

Large Gymnasium--Plaster dust and debris from renovation work were widespread along the north wall. No samples of the plaster dust were collected.

Other Considerations

The School's Asbestos Management Plan identified plaster as an asbestos-containing building material (ACBM). Samples taken by the NJDOH were reported as either 1 percent chrysotile asbestos, <1 percent chrysotile asbestos, or as negative for asbestos (Table B-81). Although none of these materials tested greater than 1 percent asbestos, the Asbestos Management Plan classified them as friable surfacing materials with damage and indicated that repairs would be made by September 1, 1989. At the time of the NJDOH inspection, no repairs had been made, however, the plaster debris on the floor surfaces in the large gymnasium had been cleaned up.

Conclusions

The deterioration of the plaster in the building and activities involved in the renovation and repair of the plaster may have contributed to the elevated concentrations of airborne asbestos measured in May 1991.

TABLE B-81. SUMMARY OF BULK SAMPLE RESULTS--SITE M 1991 INSPECTION

Location	Type of material	Analyses
1988 Abatement Area		
Basement recreation room/classroom	Plaster, top coat	Negative
Basement hallway	Plaster, top coat	Negative
Basement hallway	Plaster, browncoat	Positive[a], chrysotile asbestos
1988 Perimeter Area		
Boiler room, coal area	Debris mixed in coal	3% chrysotile, 19% amosite, positive, crocidolite asbestos
Boiler room, coal area	TSI debris	Positive, chrysotile asbestos
Boiler room, under stairs	TSI debris	67% chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

SITE N

Background

Site Description

During the summer of 1988, asbestos-containing acoustical ceiling plaster was removed from Site N. The Site N abatement involved the removal of approximately 11,000 ft^2 of ceiling plaster from an "egg crate" design concrete ceiling. The abatement area included corridors, mechanical arts classrooms, and offices. The acoustical plaster contained 10 to 25 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

During the summer of 1991, 75,600 square feet of asbestos-containing ceiling plaster was abated. There has been no other abatement activity between 1988 and 1992.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside of the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST.

In 1990, air samples were collected at this school by a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988.

In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-82 summarizes the air monitoring results from the four sampling efforts. Figure B-14 illustrates the mean airborne asbestos concentrations at Site N. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-83. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-82. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE N[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors[b] (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.100	0.076	0.129	0.003	0	0.016	0.004	0.004	0.004
Simulated occupancy- 1990	0.007	0	0.031	0.004	0	0.011	0.001	0	0.005
Occupied conditions- 1991	0.004	0.003	0.009	0.015	0	0.046	0	0	0
Occupied conditions- 1992	0.004	0.002	0.008	0.006	0.003	0.013	0.004	0	0.012

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Outdoor samples are the same as those collected at Site K in 1990, 1991, and 1992 (Site N was the second abatement project at this school in 1988).

TABLE B-83. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE N

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.0001	A(0.100) O(0.004) P(0.003)
Simulated occupancy-1990	0.6268	A(0.007) P(0.004) O(0.001)
Occupied conditions-1991	0.0125	P(0.015) A(0.004) O(0)
Occupied conditions-1992	0.2949	P(0.006) A(0.004) O(0.004)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

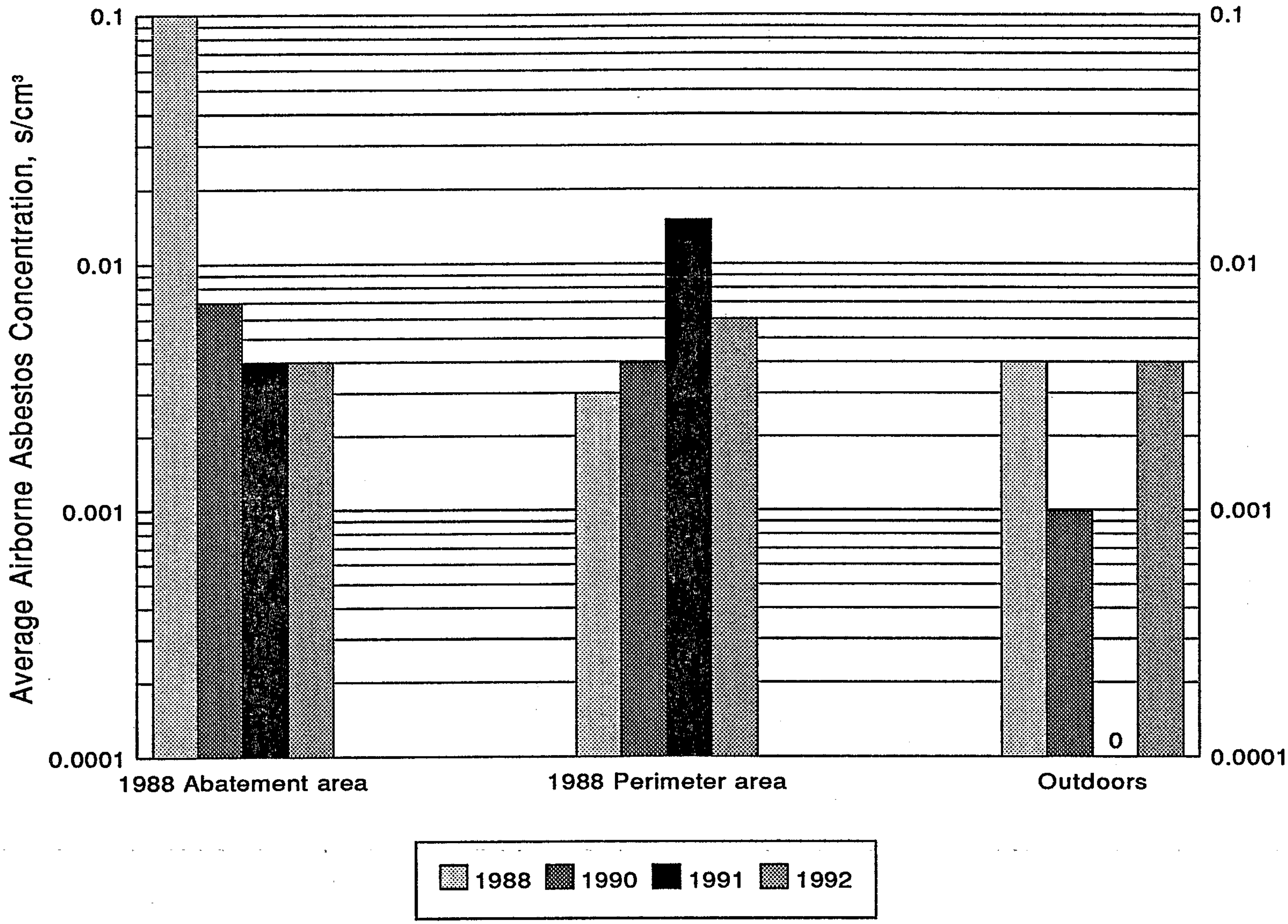

Figure B-14. Average airborne asbestos concentrations measured at Site N.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (663 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.100 s/cm^3) was significantly greater than the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.100 s/cm^3) was significantly greater than the average concentration measured in the perimeter areas (0.003 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.004 s/cm^3) was not significantly different from the average outdoor concentration (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.007 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.004 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.015 s/cm^3) was significantly greater than the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.015 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.006 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.006 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. The result of the ANOVA analysis is presented in Table B-84, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-84. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE N

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0001	1988(0.100) 1990(0.007) 1991(0.004) 1992(0.004)
Perimeter area	0.2248	1991(0.015) 1992(0.006) 1990(0.004) 1988(0.003)
Outdoors	0.0282	1988(0.004) 1992(0.004) 1990(0.001) 1991(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

The average airborne asbestos concentrations measure during the AHERA clearance phase of the 1988 abatement (0.100 s/cm^3) was significantly greater than the average concentrations measured during simulated occupancy in 1990 (0.007 s/cm^3) and during occupied conditions in 1991 (0.004 s/cm^3) and in 1992 (0.004 s/cm^3). Differences between average airborne asbestos concentrations measured during occupied conditions in 1990, 1991 and 1992 were not statistically significant. The highest average concentration (0.100 s/cm^3) and the highest individual concentration (0.129 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

1988 Perimeter Area

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentrations (0.015 s/cm^3) were measured during occupied conditions in 1991 and 1992 and the highest individual concentrations (0.006 s/cm^3) were measured during occupied conditions in 1991, 3 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1988 was significantly greater than the average concentration measured in 1991. Other differences in the average concentrations measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentrations (0.004 s/cm^3) were measured in 1988 and in 1992 and the highest individual concentration (0.012 s/cm^3) was measured in 1992.

Structure Morphology and Size Distributions

Table B-85 presents the distribution of structure type and morphology at each sampling location for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 203 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (72.9 percent), and to a lesser extent, matrices (19.2 percent), clusters (4.9 percent), and bundles (3.0 percent).

Table B-86 presents the cumulative size distribution of asbestos samples at each sampling location for each year of monitoring. Overall, 96.6 percent of the observed asbestos structures were less than 5 µm in length. Of the 148 asbestos fibers observed, only 2 (1.4 percent) were greater than 5 µm in length.

TABLE B-85. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE N

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	126	100	0	65.1	3.2	7.9	23.8
	1990	7	100	0	100	0	0	0
	1991	7	100	0	71.4	14.3	0	14.3
	1992	8	100	0	87.5	0	0	12.5
Perimeter area	1988	4	100	0	75	0	0	25
	1990	4	100	0	100	0	0	0
	1991	23	100	0	78.3	0	0	21.7
	1992	12	100	0	100	0	0	0
Outdoors[b]	1988	5	100	0	80	0	0	20
	1990	1	100	0	0	100	0	0
	1991	0	-	-	-	-	-	-
	1992	6	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Outdoor samples are the same as those collected at Site K in 1990, 1991, and 1992 (Site N was the second abatement project at this school in 1988).

TABLE B-86. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE N

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	126	34.9	76.2	88.1	91.3	95.2	100
	1990	7	71.4	100	100	100	100	100
	1991	7	57.1	100	100	100	100	100
	1992	8	75	100	100	100	100	100
Perimeter area	1988	4	100	100	100	100	100	100
	1990	4	100	100	100	100	100	100
	1991	23	73.9	95.7	95.7	95.7	95.7	100
	1992	12	66.7	100	100	100	100	100
Outdoors[b]	1988	5	60	100	100	100	100	100
	1990	1	0	100	100	100	100	100
	1991	0	-	-	-	-	-	-
	1992	6	100	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Outdoor samples are the same as those collected at Site K in 1990, 1991, and 1992 (Site N was the second abatement project at this school in 1988).

Followup Air Monitoring - August 1991

Although the average airborne asbestos concentrations in the previously abated area and in the perimeter area did not exceed 0.02 s/cm^3 in May 1991, EPA/NJDOH conducted followup monitoring under simulated occupancy conditions on August 14, 1991, because the average airborne asbestos concentration in the previously abated area from another abatement project at this school (Site K) did exceed 0.02 s/cm^3. The August 14 results revealed that the average airborne asbestos concentrations in the previously abated area and in perimeter areas of Site N were below 0.02 s/cm^3; therefore, no further monitoring activity was required at this site.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site N as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Two visual inspections were required at this site. The site failed the first visual inspection because debris was present on light fixtures, on the tops of heating elements, on conduit pipe, on the walls behind ventilation ducts, and on the floors. The contractor was then required to reclean these areas. When the areas were recleaned, NJDOH conducted a second visual inspection, which the site passed.

1991 Inspection

On August 15, 1991, an NJDOH Visual Inspection was conducted at Sites K and N to determine potential sources of airborne asbestos measured by EPA/NJDOH in April 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined.

1988 Abatement Areas

Refrigeration/AC Room, Mechanical (Engine) Room--Surface dust was noted but not sampled.

1988 Perimeter Areas

Classrooms, Mechanical Arts Room--Surface dust was noted but not sampled. The floor tile in classrooms was not identified as ACM in the Asbestos Management Plan.

Conclusions

Asbestos materials in the brake and clutch assemblies in various high speed equipment could be a possible source of airborne asbestos. The misidentification of VAT in the Asbestos Management Plan could also lead to uncontained VAT removals, improper O&M and possible contamination.

SITE O

Background

Site Description

The abatement project at this two-story school involved the removal of approximately 2,100 ft^2 of 2-ft by 4-ft lay-in, asbestos-containing, acoustical ceiling tiles. The abatement area included corridors, classrooms, and offices. The project specifications indicated that the asbestos content of the ceiling plaster was approximately 5 to 10 percent amosite. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-87 summarizes the results from the four sampling efforts. Figure B-15 illustrates the mean airborne asbestos concentrations at Site O. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-88. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (31 s/mm^2) was

TABLE B-87. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE O[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.004	0.003	0.007	0.003	0	0.010	0.001	0	0.004
Simulated occupancy- 1990	0.001	0	0.005	0.018	0	0.086	0.001	0	0.005
Occupied conditions- 1991	0.005	0	0.022	0	0	0	0.001	0	0.003
Occupied conditions- 1992	0.002	0	0.005	0.001	0	0.003	0.027	0.012	0.047

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-88. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE O

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.1084	A(0.004) P(0.003) O(0.001)
Simulated occupancy-1990	0.4478	P(0.018) A(0.001) O(0.001)
Occupied conditions-1991	0.3298	A(0.005) O(0.001) P(0)
Occupied conditions-1992	0.0001	O(0.027) A(0.002) P(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

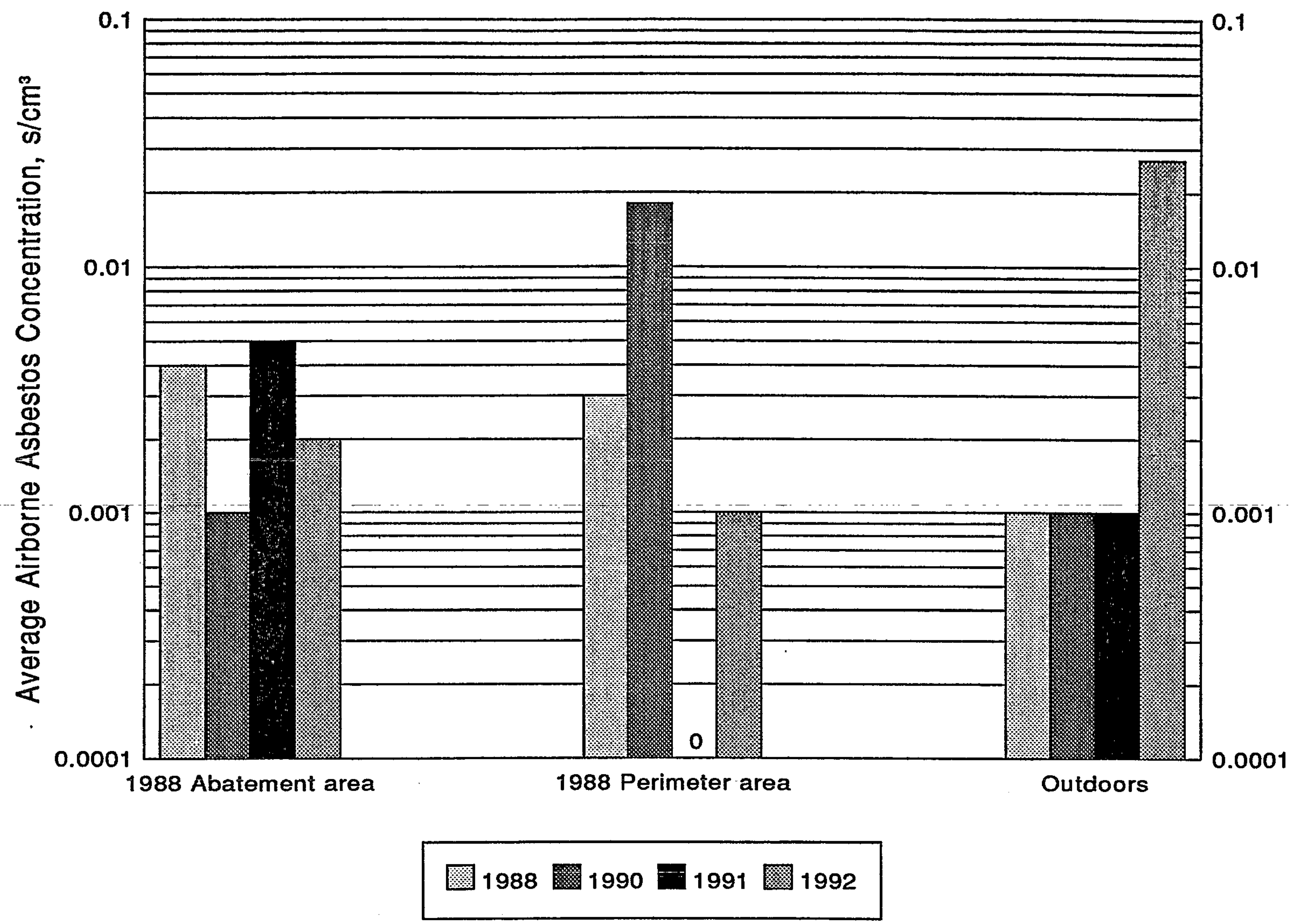

Figure B-15. Average airborne asbestos concentrations measured at Site O.

below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.004 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.003 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.018 s/cm^3) was not significantly different from the average outdoor concentration (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.018 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.002 s/cm^3) was significantly less than the average concentration measured outdoors (0.027 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was significantly less than the average concentration measured outdoors (0.027 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.002 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-89 presents the result of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-89. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE O

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.3566	1988(0.004) 1991(0.005) 1992(0.002) 1990(0.001)
Perimeter area	0.4144	1990(0.018) 1988(0.003) 1992(0.001) 1991(0)
Outdoors	0.0001	1992(0.027) 1988(0.001) 1990(0.001) 1991(0.001)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

Differences between average airborne asbestos concentrations measured during occupied conditions in 1988, 1990, 1991 and 1992 were not statistically significant. The highest average concentration (0.005 s/cm^3) and the highest individual concentration (0.022 s/cm^3) were measured during occupied conditions in 1991, 3 years after abatement.

Perimeter

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentrations (0.018 s/cm^3) and the highest individual concentrations (0.086 s/cm^3) were measured during simulated occupancy conditions in 1990, 2 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1992 was significantly greater than the average concentration measured in 1988, 1990, and 1991. Differences in the average concentrations measured in 1988, 1990, 1991 were not statistically significant. The highest average concentrations (0.027 s/cm^3) and the highest individual concentration (0.047 s/cm^3) was measured in 1992.

Structure Morphology and Size Distributions

Table B-90 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 95 asbestos structures, of which 97.9 percent were chrysotile asbestos and 2.1 percent of which were amphibole asbestos. Overall, the asbestos structures were primarily fibers (80 percent), and to a lesser extent, matrices (10.5 percent), clusters (5.3 percent), and bundles (4.2 percent).

Table B-91 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. All of the observed asbestos structures were less than 5 µm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site O as part of the State's traditional quality assurance program. This provides a check and balance to asbestos abatement and ensures that high-quality abatement and state-of-the art work practices are used. The onsite AST collected AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

TABLE B-90. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE O

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	6	83.3	16.7	83.3	0	0	16.7
	1990	1	100	0	100	0	0	0
	1991	8	100	0	100	0	0	0
	1992	4	100	0	50	0	0	50
Perimeter area	1988	5	100	0	20	0	20	60
	1990	19	100	0	68.4	0	21.1	10.5
	1991	0	-	-	-	-	-	-
	1992	2	50	50	50	0	0	50
Outdoors	1988	1	100	0	100	0	0	0
	1990	1	100	0	100	0	0	0
	1991	2	100	0	100	0	0	0
	1992	46	100	0	89.1	8.7	0	2.2

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-91. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE O

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	6	16.7	66.7	83.3	100	100	100
	1990	1	100	100	100	100	100	100
	1991	8	50	87.5	100	100	100	100
	1992	4	50	100	100	100	100	100
Perimeter area	1988	5	0	80	80	80	100	100
	1990	19	26.3	78.9	100	100	100	100
	1991	0	-	-	-	-	-	-
	1992	2	50	100	100	100	100	100
Outdoors	1988	1	100	100	100	100	100	100
	1990	1	100	100	100	100	100	100
	1991	2	50	100	100	100	100	100
	1992	46	84.8	97.8	97.8	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Two visual inspections were required at this site. The site failed the first visual inspection because debris was present on overhead pipes, on the grid system framework for suspended ceiling panels, and in corners of floor-wall intersections. The contractor was then required to reclean these areas. Once the areas were recleaned, NJDOH conducted a second visual inspection. The site passed the second visual inspection.

1991 Visual Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, on October 29, 1991, NJDOH conducted a visual inspection at Site O as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in October 1991.

1988 Abatement Areas

First Floor Corridor and Stairwell--Minor debris (flakes that tested positive for chrysotile asbestos) was obtained from the lip of a suspended Nesbitt heater unit (Table B-92) Other flakes of debris found on a wall tested negative for asbestos. Fiberglass pipe insulation with cementitious elbows and joints was noted above the drop ceiling. Debris recovered near an elbow above the drop ceiling at a water fountain tested positive (6 percent chrysotile, 21 percent amosite asbestos). Another sample, taken from an elbow, tested negative for asbestos. These materials are not listed in the Asbestos Management Plan.

Second Floor Corridor--This inspection was limited by heavy fiberglass batting applied atop the drop ceilings. No debris was found in this area.

1988 Perimeter Areas

Hallway at Gym and Boiler Room--No suspect asbestos-containing thermal system insulation was found.

Boiler Room--Approximately 5 linear feet of corrugated pipe insulation (22 percent chrysotile asbestos) with damaged friable elbow insulation (4 percent chrysotile, 4 percent amosite asbestos) was found (Table B-92). This material was apparently overlooked during abatement.

Pipe Tunnel--Thermal debris (1 percent chrysotile, 4 percent amosite asbestos) was found at the entry to the tunnel (Table B-92).

TABLE B-92. SUMMARY OF BULK SAMPLE RESULTS -- SITE O 1991 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Areas		
North stairwell	Encapsulated flakes on wall	Negative
South stairwell	Residue on Nesbitt heater	Positive[a], chrysotile asbestos
Corridor 1st level	Elbow with fiberglass insulation	Negative
Corridor 1st level	Elbow debris at water fountain	6% chrysotile asbestos 21% amosite asbestos
1988 Perimeter Areas		
Boiler room	NE corner - corrugated pipe insulation	22% chrysotile asbestos
Boiler room	N/E corner - elbow	4% chrysotile asbestos <1% amosite asbestos
Pipe tunnel entry	Thermal debris	1% chrysotile asbestos 4% amosite asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Basement of New Wing--Room 114 and Science Storage have cementitious elbows associated with fiberglass pipe insulation. These materials do not appear in the Asbestos Management Plan.

Conclusions

A number of asbestos sources were identified in the various areas of the building. The school's Asbestos Management Plan must be revised to reflect the presence of these materials.

SITE P

Background

Site Description

The abatement project at this three-story school building involved the removal of trowel-applied, asbestos-containing, acoustical ceiling plaster and mixed-diameter pipe insulation. The abatement area included corridors, classrooms, and offices. The project specifications indicated that the abatement involved the removal of approximately 8500 ft^2 of acoustical ceiling plaster containing 91 to 93 percent chrysotile and approximately 1600 linear feet of mixed-diameter pipe insulation. The latter included hard-packed pipe insulation (24 percent chrysotile), air-cell-paper pipe insulation (4 to 10 percent chrysotile), and hard-packed joint insulation (60 percent chrysotile). The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-93 summarizes the results of the five sampling efforts. Figure B-16 shows the mean airborne asbestos concentrations at Site P. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-94 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-93. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE P[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0.001	0	0.005	0	0	0
Postabatement-1988	0.005	0	0.011	0.007	0	0.018	0.003	0	0.016
Simulated occupancy- 1990	0.005	0	0.025	0	0	0	0	0	0
Occupied conditions- 1991	0.004	0	0.011	0.001	0	0.004	0	0	0
Occupied conditions- 1992	0.003	0	0.010	0.006	0	0.020	0.009[c]	0	0.018

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

[c] N = 4.

TABLE B-94. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE P

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.3466	P(0.001) O(0)
Postabatement-1988	0.4285	P(0.007) A(0.005) O(0.003)
Simulated occupancy-1990	0.3966	A(0.005) P(0) O(0)
Occupied conditions-1991	0.0891	A(0.004) P(0.001) O(0)
Occupied conditions-1992	0.4714	O(0.009) P(0.006) A(0.003)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

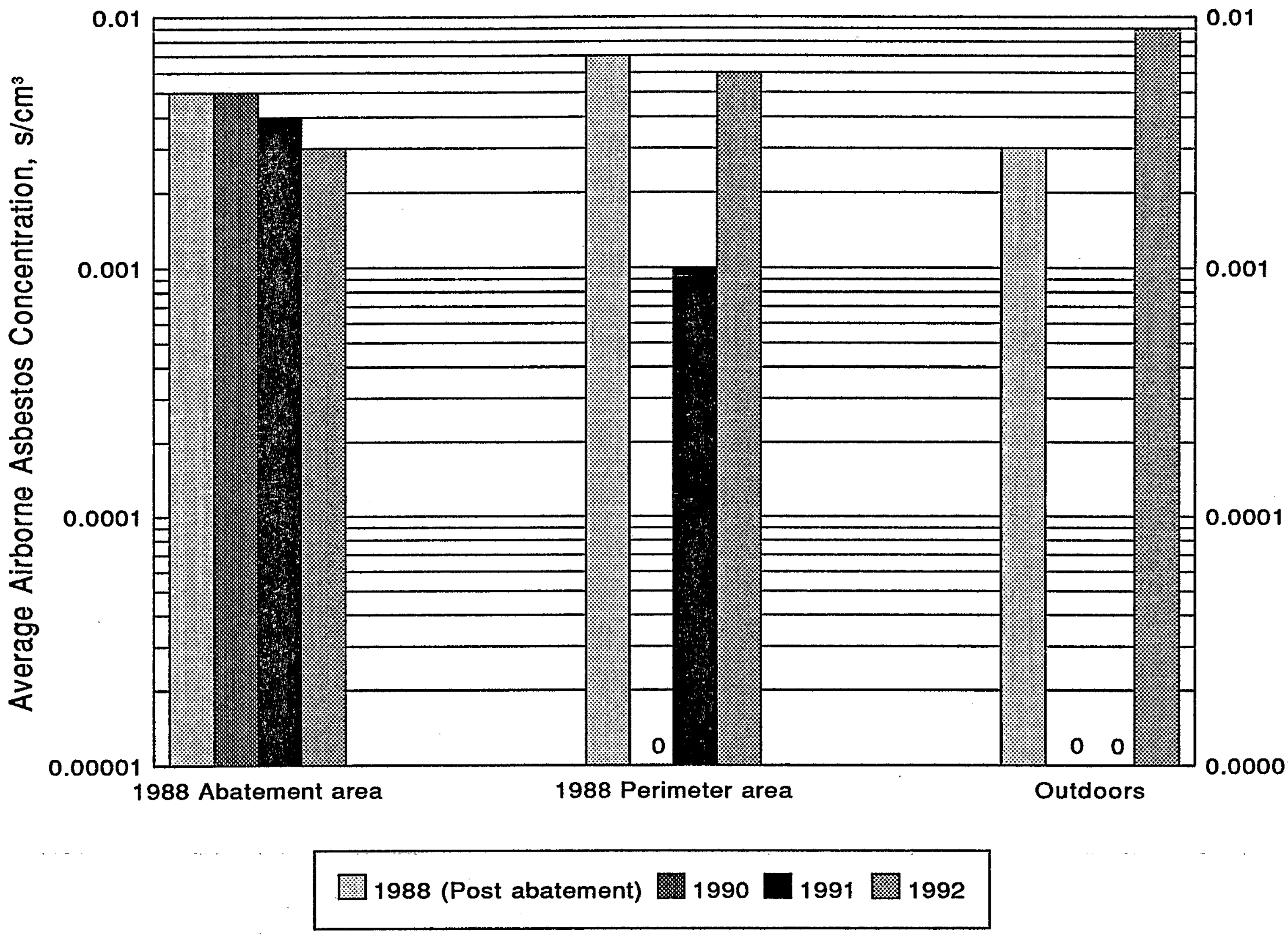

Figure B-16. Average airborne asbestos concentrations measured at Site P.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement in 1988 (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the AHERA initial screening test because the average filter concentration (30 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.007 s/cm^3) was not significantly different from the average concentration measured outdoors (0.003 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.005 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.007 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.004 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.009 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.006 s/cm^3) was not significantly different from the average concentration measured outdoors (0.009 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.006 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-95 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

Differences between average airborne asbestos concentrations measured during occupied conditions in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentrations (0.005 s/cm^3) were measured in 1988 and 1990, and the highest individual concentration (0.025 s/cm^3) was measured during simulated occupancy in 1990, 2 years after abatement.

Perimeter

The average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not significantly different. The highest average concentration (0.007 s/cm^3) was measured during the AHERA clearance phase of the 1988 abatement, and the highest individual concentration (0.020 s/cm^3) was measured during occupied conditions in 1992, four years after the 1988 abatement.

TABLE B-95. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE P

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.9024	1988(0.005) 1990(0.005) 1991(0.004) 1992(0.003)
Perimeter area	0.0856	1988(0.007) 1992(0.006) 1991(0.001) 1988P(0.001) 1990(0)
Outdoors	0.0088	1992(0.009) 1988(0.003) 1990(0) 1991(0) 1988P(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1992 was significantly greater than the average concentration measured preabatement in 1988, in 1990 and 1991, but not significantly different from the average postabatement concentration measured in 1988. Differences in the average concentrations measured in 1988, 1990, and 1991 were not statistically significant. The highest average concentration (0.009 s/cm^3) and the highest individual concentration (0.018 s/cm^3) were measured in 1992.

Structure Morphology and Size Distributions

Table B-96 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 61 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (73.8 percent), and to a lesser extent, matrices (16.4 percent), clusters (6.6 percent), and bundles (3.3 percent).

TABLE B-96. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE P

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	6	100	0	33.3	0	16.7	50
	1990	5	100	0	80	0	20	0
	1991	5	100	0	20	0	0	80
	1992	6	100	0	100	0	0	0
Perimeter area	1988	9	100	0	88.9	0	0	11.1
	1990	0	-	-	-	-	-	-
	1991	1	100	0	0	0	100	0
	1992	12	100	0	91.7	0	0	8.3
Outdoors	1988	4	100	0	25	25	25	25
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	13	100	0	92.3	7.7	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

Table B-97 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 98.4 percent of the observed asbestos structures were less than 5 µm in length. Of the 45 asbestos fibers observed, only 1 (2.2 percent) was greater than 5 µm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site P as part of the State's traditional quality assurance program, which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Three visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on pipes, in openings where the pipes penetrated the walls, on electrical fixtures and wires, in door jambs, at ceiling-wall junctions, on walls, inside a fireplace and chimney, and in a sink used for disposal of asbestos-contaminated wastewater. The contractor was then required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of debris found behind the fireplace, at ceiling-wall junctions, and on floors and residual slurry found on walls and underneath stairs. After these areas were recleaned, NJDOH conducted a third visual inspection which the site passed.

1991 Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, NJDOH conducted a visual inspection at Site P on November 5, 1991 as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in November 1991.

1988 Abatement Areas

Kindergarten Room--Unencapsulated residual ceiling material was noted on the top of the windows and exterior aluminum wall columns (Table B-98). Encapsulated and painted material was noted at the ceiling and wall junctions. Approximately 35 linear feet of corrugated pipe insulation was found in the space above the lavatory and the closet storage area. These pipes do not appear in the Asbestos Management Plan.

TABLE B-97. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE P

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	6	16.7	66.7	83.3	83.3	83.3	100
	1990	5	20	80	100	100	100	100
	1991	5	80	100	100	100	100	100
	1992	6	83.3	100	100	100	100	100
Perimeter area	1988	9	33.3	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	1	100	100	100	100	100	100
	1992	12	100	100	100	100	100	100
Outdoors	1988	4	25	75	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	0	-	-	-	-	-	-
	1992	13	92.3	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-98. SUMMARY OF BULK SAMPLE RESULTS - SITE P
1991 INSPECTION

Location	Type of Material	Analyses
<u>1988 Abatement Area</u>		
Kindergarten (KDGA)	Spray-on residue at top of windows	Positive[a] for chrysotile asbestos
KDGA	Dust inside radiator	Negative
KDGA	Painted over residue on wall at ceiling and wall junctions	Positive for chrysotile asbestos
SW Stairwell	Floor tile debris under radiator	8% Chrysotile asbestos
<u>1988 Perimeter Areas</u>		
2nd Floor classroom	Dust inside radiator	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

First Floor Corridor, 1965 Wing--Pipe insulation was observed in the plenum above the hallway through a new penetration. Intercom-type wire had recently been run on top of this insulation. This material does not appear in the Asbestos Management Plan.

Classroom No. 2--From a closet overhead area, pipe insulation was noted to be running through vertical shafts along the exterior wall. Pipe insulation was also visible above the corridor ceilings. These materials do not appear in the Asbestos Management Plan.

1988 Perimeter Areas

1st Floor Corridor, Old Wing--Thermal system insulation was noted in the plenum above the hallway. This material is listed in the Asbestos Management Plan.

Foyer Chase--The floor under the entry foyer contains thermal system insulation that is not listed in the Asbestos Management Plan.

Girls Lavatory, 1st Floor--Inaccessible thermal systems insulation was observed. The Asbestos Management Plan does not list these remaining materials.

Boiler Room--Packing and lag were noted around the caps on top of the boilers and are not included in the Asbestos Management Plan.

Pump Room--Debris was noted at the entrance to the pipe tunnels.

Conclusions

TSI was present in the 1988 abatement and perimeter areas, but not listed in the Management Plan and the potential for disturbance exists. Residual materials are located above the suspended ceiling and as such, would not be disturbed during subsequent air sampling.

SITE Q

Background

Site Description

During the summer of 1988, two asbestos abatement projects were conducted at this school (Sites B and Q). Spray-applied acoustical ceiling plaster was removed from the second floor (Site B) and from the first floor (Site Q). The abatement areas at both sites included corridors, classrooms, and offices. The ceiling plaster contained approximately 2 to 6 percent chrysotile asbestos. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site. No additional abatement activity has occurred since 1988.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area, but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter area and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-99 summarizes the results from 1988, 1990, 1991, and 1992. Figure B-17 shows the mean airborne asbestos concentrations at Site Q. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-100. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

TABLE B-99. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE Q[a]

Sampling period	Abatement area (N=5)			Perimeter area[b] (N=5)			Outdoors[b] (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[c]	-	-	0.001	0	0.004	0	0	0
Postabatement-1988	0.099	0.029	0.157	0.055	0	0.115	0.007	0	0.021
Simulated occupancy- 1990	0.019	0	0.040	0.010	0	0.040	0.001	0	0.005
Occupied conditions- 1991	0.009	0	0.018	0.012	0.004	0.024	0.001	0	0.004
Occupied conditions- 1992	0.053	0.025	0.104	0.438	0.142	1.02	0.001	0	0.003

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Perimeter and Outdoor samples are the same as those collected at Site B in 1990, 1991, and 1992 (Site Q was the second abatement project at this school in 1988).

[c] Abatement area was not accessible for preabatement sampling.

TABLE B-100. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE Q

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.3466	P(0.001) O(0)
Postabatement-1988	0.0095	A(0.099) P(0.055) O(0.007)
Simulated occupancy-1990	0.0907	A(0.019) P(0.010) O(0.001)
Occupied conditions-1991	0.0059	P(0.012) A(0.009) O(0.001)
Occupied conditions-1992	0.0001	P(0.438) A(0.053) O(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

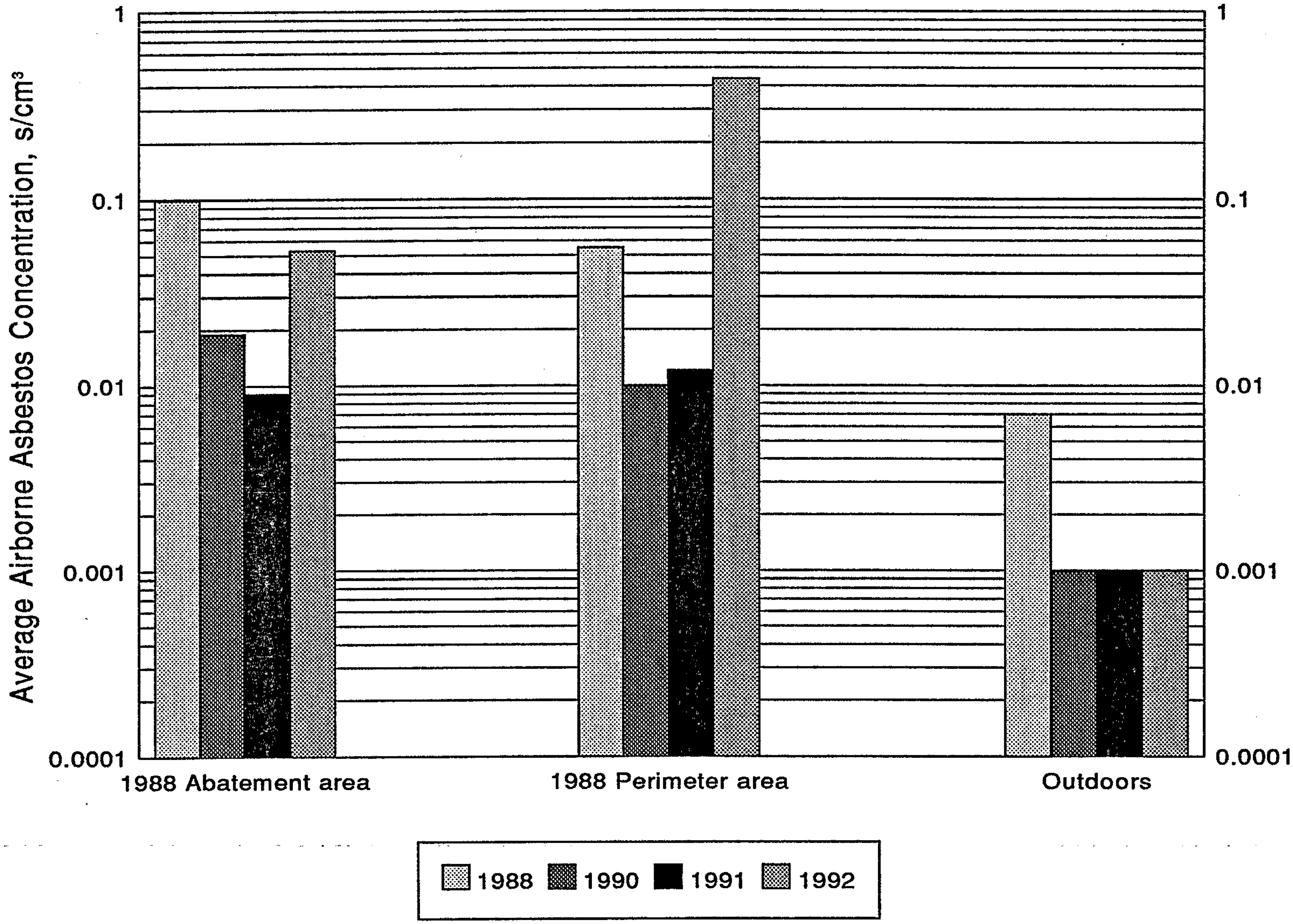

Figure B-17. Average airborne asbestos concentrations measured at Site Q.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (648 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.099 s/cm^3) was significantly greater than the average concentration measured outdoors (0.007 s/cm^3). This result is consistent with the AHERA Z-test comparison reported previously.

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0.055 s/cm^3) was not significantly different from the average concentration measured outdoors (0.007 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.099 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.055 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the previously abated area 2 years after the 1988 abatement (0.019 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 2 years after the 1988 abatement (0.010 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.019 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter area (0.010 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.009 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.012 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.009 s/cm^3) was not significantly different from the average airborne asbestos concentration measured in the perimeter area (0.012 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.053 s/cm^3) was significantly greater than the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Areas With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.438 s/cm^3) was significantly greater than the average outdoor concentration of airborne asbestos (0.001 s/cm^3). The unusually high average level in the perimeter areas is due primarily to one sample (1.02 s/cm^3); the other four samples ranged from 0.014 to 0.038 s/cm^3.

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.053 s/cm^3) was significantly less than the average airborne asbestos concentration measured in the perimeter area (0.438 s/cm^3). The unusually high average level in the perimeter area is due primarily to one sample (1.02 s/cm^3); the other four samples ranged from 0.014 to 0.038 s/cm^3.

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-101 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

1988 Abatement Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.099 s/cm^3) was significantly greater than the average concentrations measured during simulated occupancy in 1990 (0.019 s/cm^3) and during occupied conditions in 1991 (0.009 s/cm^3), but not significantly different from the average concentration measured during occupied conditions in 1992 (0.053 s/cm^3). Furthermore, the average concentration measured during occupied conditions in 1992 was significantly higher than the average concentration measured in 1991. Other differences between average concentrations were not statistically significant. The highest average concentration (0.099 s/cm^3) and the highest individual concentration (0.157 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

TABLE B-101. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE Q

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0019	1988(0.099) 1992(0.053) 1990(0.019) 1991(0.009)
Perimeter area	0.0002	1992(0.438) 1988(0.055) 1991(0.012) 1990(0.010)
Outdoors	0.1871	1988(0.007) 1990(0.001) 1991(0.001) 1992(0.001)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

Perimeter Area

The average airborne asbestos concentrations measured in the perimeter area in 1992, 4 years after the 1988 abatement (0.438 s/cm^3), was significantly higher than the average levels measured in 1988, 1990, and 1991. The differences between the average levels in 1988, 1990, and 1991 were not statistically significant. The highest average concentration (0.438 s/cm^3) and the highest individual concentration (1.02 s/cm^3) were measured in 1992 4 years after the 1988 abatement.

Outdoors

Differences in average airborne asbestos concentration measured outdoors in each of the 4 years were not statistically significant. The highest individual concentration (0.021 s/cm^3) was measured in 1988 during the AHERA clearance phase of the abatement.

Structure Morphology and Size Distributions

Table B-102 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 889 asbestos structures, of which 99.7 percent were chrysotile asbestos and 0.3 percent were amphibole. Overall, the asbestos structures were primarily fibers (92.2 percent), and to a lesser extent, matrices (5.4 percent), clusters (1.5 percent), and bundles (0.9 percent).

Table B-103 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 98.7 percent of the observed asbestos structures were less than 5 μm in length. Of the 820 asbestos fibers observed, only 4 fibers (0.5 percent) were greater than 5 μm in length.

Followup Air Monitoring - August 1991

Although the average airborne asbestos concentration in the previously abated area and the perimeter area in May 1991 did not exceed 0.02 s/cm^3, EPA/NJDOH conducted followup monitoring on August 13, 1991, under simulated occupancy conditions because the average airborne asbestos concentration in the previously abated area from another abatement project at this school (Site B) did exceed 0.02 s/cm^3. The August 13 results showed that the average airborne asbestos concentration in the previously abated area and perimeter area of Site Q were below 0.02 s/cm^3; therefore, no further monitoring activity was required.

Followup Air Monitoring - August 1992

Because the average airborne asbestos concentrations in the previously abated area (0.053 s/cm^3) and the perimeter area (0.438 s/cm^3), EPA/NJDOH conducted followup monitoring in July 1992 under simulated occupancy conditions to determine whether airborne asbestos concentration were still present at the levels observed in May 1992. The average airborne asbestos concentration measured in the perimeter area in July (0.006 s/cm^3) was below 0.02 s/cm^3; therefore, no further action was required in this area. The NJDOH did, however, require a response action in the previously abated area at this school, based on the May 1992 data. The school subsequently employed a licensed asbestos-abatement contractor to clean the previously abated area. When the cleaning action was complete, NJDOH conducted followup air monitoring in August 1992 to determine the residual levels of airborne asbestos. The average airborne asbestos concentration measured in August (0.009 s/cm^3) was below 0.02 s/cm^3; therefore, no further monitoring activity was required at this school.

TABLE B-102. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE Q

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	129	99.2	0.8	79.8	0	4.7	15.5
	1990	19	89.5	10.5	78.9	5.3	0	15.8
	1991	13	100	0	92.3	0	0	7.7
	1992	97	100	0	95.9	3.1	0	1
Perimeter area[b]	1988	75	100	0	66.7	0	9.3	24
	1990	10	100	0	100	0	0	0
	1991	17	100	0	88.2	0	0	11.8
	1992	518	100	0	99.2	0.8	0	0
Outdoors[b]	1988	8	100	0	62.5	0	0	37.5
	1990	1	100	0	100	0	0	0
	1991	1	100	0	100	0	0	0
	1992	1	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Perimeter and outdoor samples are the same as those collected at Site B in 1990, 1991, and 1992 (Site Q was the second abatement project at this school in 1988).

TABLE B-103. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE Q

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 μm	≤2 μm	≤3 μm	≤4 μm	≤5 μm	≤10 μm
Abatement area	1988	129	52.7	86.8	93	95.3	96.9	98.4
	1990	19	42.1	89.5	89.5	89.5	89.5	94.7
	1991	13	53.8	100	100	100	100	100
	1992	97	81.4	97.9	100	100	100	100
Perimeter area[b]	1988	75	41.3	78.7	89.3	92	92	97.3
	1990	10	60	90	100	100	100	100
	1991	17	70.6	100	100	100	100	100
	1992	518	77.8	99.6	99.8	100	100	100
Outdoors[b]	1988	8	37.5	75	87.5	87.5	100	100
	1990	1	100	100	100	100	100	100
	1991	1	0	100	100	100	100	100
	1992	1	0	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Perimeter and outdoor samples are the same as those collected at Site B in 1990, 1991, and 1992 (Site Q was the second abatement project at this school in 1988).

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site Q as part of the State's traditional quality assurance program, which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Four visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on the tops of storage closets and on structural beams. The contractor was then required to reclean these areas. After the areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of debris in openings at wall penetrations and on several light fixtures. The contractor was again required to reclean the affected areas. After the areas were recleaned, NJDOH conducted a third visual inspection. The site failed the third visual inspection because of debris at wall-ceiling junctions, in door jambs, and in corners of window sills. After these areas were recleaned, NJDOH conducted a fourth visual inspection. The site passed the fourth visual inspection with the stipulation that the overhead area be sprayed with encapsulant.

Background for 1991 and 1992 Inspections

On August 14, 1991, and July 16, 1992, NJDOH conducted a visual inspection at Sites B and Q to determine potential sources of airborne asbestos measured by EPA and NJDOH in May 1991. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in August 1991 and July 1992.

1991 Inspection

1988 Abatement Areas

Two samples of overspray and debris were collected from the structural steel and closet overhead areas in the first-floor classrooms (Table B-104); one sample of spray-on debris tested positive for chrysotile asbestos, and a sample of sandy debris from an air shaft tested negative for asbestos.

TABLE B-104. SUMMARY OF BULK SAMPLE RESULTS--SITE Q 1991 INSPECTION

Location	Type of material	Analyses
<u>1988 Abatement Area</u>		
1st floor classroom	Flakes of spray-on debris	Positive, chrysotile asbestos
1st floor classroom, air shaft ledge	Flakes of spray-on debris	Negative
<u>1988 Perimeter Areas</u>		
Basement all-purpose room	Composite, ceiling sample	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

1988 Perimeter Areas

In the basement all-purpose room, thermal system insulation (TSI) not identified in the Asbestos Management Plan was observed in the ceiling overhead spaces in the corridor, kitchen, and storage closet. This material appeared to be in generally good condition.

Conclusions

Incomplete assessment and abatement failed to account for overspray in the ceiling overhead spaces and the closet recessions. These asbestos-containing materials could have contributed to the elevated airborne asbestos levels measured in May 1991.

1992 Inspection

1988 Abatement Area

First-Floor Classrooms--In 1991, the NJDOH inspectors found residual spray-applied asbestos-containing material on the black iron trusses above the ceilings and ventilation panels in closets of the classrooms. Samples of this material showed it to contain asbestos (Table B-105). The black iron trusses support the wire lathe, scratch coat, and acoustical plaster layers that make up the ceiling system in each classroom. The ceilings of the closets consist of wood paneling and a metal ventilation panel. The flakes of asbestos-containing acoustical plaster on the trusses appeared to be the result of overspraying the scratch coat, which took place before the storage closets were installed. Overspray material was also observed on the trusses above the light fixtures, where holes for electrical connections or for mounting the fixtures were open during the spray application of the acoustical plaster.

The presence of oversprayed acoustical plaster on the trusses in the closets could not be verified during the July 16, 1992, visual inspection because the ceiling in the closets had been reinstalled and the ventilation panels were inaccessible because of stored books and other materials in the closets.

1988 Perimeter Areas

Basement All-Purpose Room--In the soffit in the all-purpose room (which is accessible through access panels in the ceiling), some air-cell-paper pipe insulation and cementitious elbows/fittings were noted. The fibrous-glass lines and cementitious fittings appeared to be in good condition; however, the air-cell-paper insulation had opened (unsealed) seams and had delaminated in a couple of areas. These materials were not identified in the Asbestos Management Plan.

Kitchen--Extensive deposits of extremely friable, white, powdery material were found inside the kitchen along the base of the exterior wall below the radiators. These deposits are believed to be caused by efflorescence of the concrete-masonry block and/or mortar. The white powdery material tested positive for asbestos (Table B-105). The flooring in the kitchen was 9 in. x 9 in. asbestos-containing (15 percent chrysotile) resilient floor tile (Table B-105). Two 15 in. by 15 in. transite hot plates were present on the grill.

Boiler Room--As shown in Table B-105, the following asbestos-containing materials were noted in the kitchen: 1) mud used to seal the boiler segments, 2) a cementitious pipe elbow debris behind the hot water tank, 3) spray-on ceiling debris in the cavity of concrete-masonry wall at the make-up air feed for the boiler, and 4) tan paint from the boiler stack. These materials were not identified in the Asbestos Management Plan.

TABLE B-105. SUMMARY OF BULK SAMPLE RESULTS - SITE Q 1992 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Area		
1st Floor S/E classroom above closet	Construction block	Negative
1st Floor S/E classroom above closet	Mortar	Negative
1988 Perimeter Areas		
Kitchen, floor at South wall	White powder	Positive[a], chrysotile asbestos
Kitchen, wood sink	White cement spray	Positive, chrysotile asbestos
Kitchen, south wall	Blue paint/white undercoat	Positive chrysotile asbestos
Kitchen, South wall on floor	White efflorescence	Positive, chrysotile asbestos
Kitchen, South wall surface	White efflorescence	Positive, chrysotile, asbestos
Kitchen, South wall	Mortar, gray cement	Negative
Kitchen, South wall	Concrete-masonry block	2% chrysotile asbestos
Kitchen by storage room	Vinyl floor tile, grey 9" x 9"	15% chrysotile asbestos
Kitchen by storage room	Mortar from floor trap	Negative
Bingo hall	Floor paint, grey	Negative
Bingo hall, East wall	Glue paint with yellow and green	1% chrysotile asbestos
Bingo hall, N/E corner	Concrete-masonry block	Negative
Bingo hall, girls room	Paint	Negative
Bingo hall, girls room	Soft debris in floor drain	Negative
Boiler room	Boiler segment mud	30% chrysotile asbestos
Boiler room	Boiler, fiber, rock wood	Negative
Boiler room, beam	Plaster/granular cement	Negative
Boiler room, ceiling pipe entry	Overspray, soft granular	Trace[b], chrysotile asbestos
Boiler room, air entry	Spray-on debris	2% chrysotile asbestos
Boiler room, chimney	Paint, tan	Positive, chrysotile asbestos
Boiler room, beam	Paint and plaster	Trace, chrysotile asbestos
Boiler room, floor	Elbow debris, hot-water heater	2% chrysotile asbestos
Boiler room	Mortar debris on pipe	Negative

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1% asbestos.

[b] Trace = <1 percent asbestos.

Conclusions

Several asbestos sources were identified that could have contributed to the elevated asbestos levels measured in 1992 (and 1991). Elevated levels in the classrooms and hallways could have been caused by disturbance of asbestos-containing dust and/or friable asbestos-containing acoustical plaster overspray on the steel trusses above the ceilings and vents in the classroom storage closets. Wind could caused air to flow from the roof vents through the ducts in this passive ventilation system and into the classrooms and hallways.

The elevated asbestos levels in the kitchen may be due to the extensive deposits of extremely friable, white, powdery material caused by efflorescence of the concrete-masonry block and/or mortar. Other possible contributory sources are the transite plates and asbestos-containing resilient floor tile.

SITE R

Background

Site Description

The abatement project at this four-story school building involved the removal of approximately 2900 linear feet of asbestos-containing thermal insulation, including mixed-diameter air-cell-paper pipe insulation and hard-packed fitting insulation. The abatement area included corridors, classrooms, offices, storage rooms, stairwells, and recreational rooms. The project specifications indicated that the asbestos content of the thermal surface insulation was approximately 10 to 25 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area, but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-106 summarizes the results from the four sampling efforts. Figure B-18 shows the mean airborne asbestos concentrations at Site R. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. The results of the ANOVA analysis are presented in Table B-107. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have passed the

TABLE B-106. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE R

Year	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Postabatement-1988	0.002	0	0.008	0	0	0	0	0	0
Simulated occupancy-1990	0	0	0	0.011	0	0.027	0.013	0	0.038
Occupied conditions-1991	0.005	0	0.010	0.001	0	0.004	0.004	0	0.012
Occupied conditions-1992	0.001	0	0.005	0.003	0	0.008	0.004	0	0.006

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-107. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE R

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Postabatement-1988	0.3966	A(0.002) P(0) O(0)
Simulated occupancy-1990	0.0237	O(0.013) P(0.011) A(0)
Occupied conditions-1991	0.3899	A(0.005) O(0.004) P(0.001)
Occupied conditions-1992	0.2505	O(0.004) P(0.003) A(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

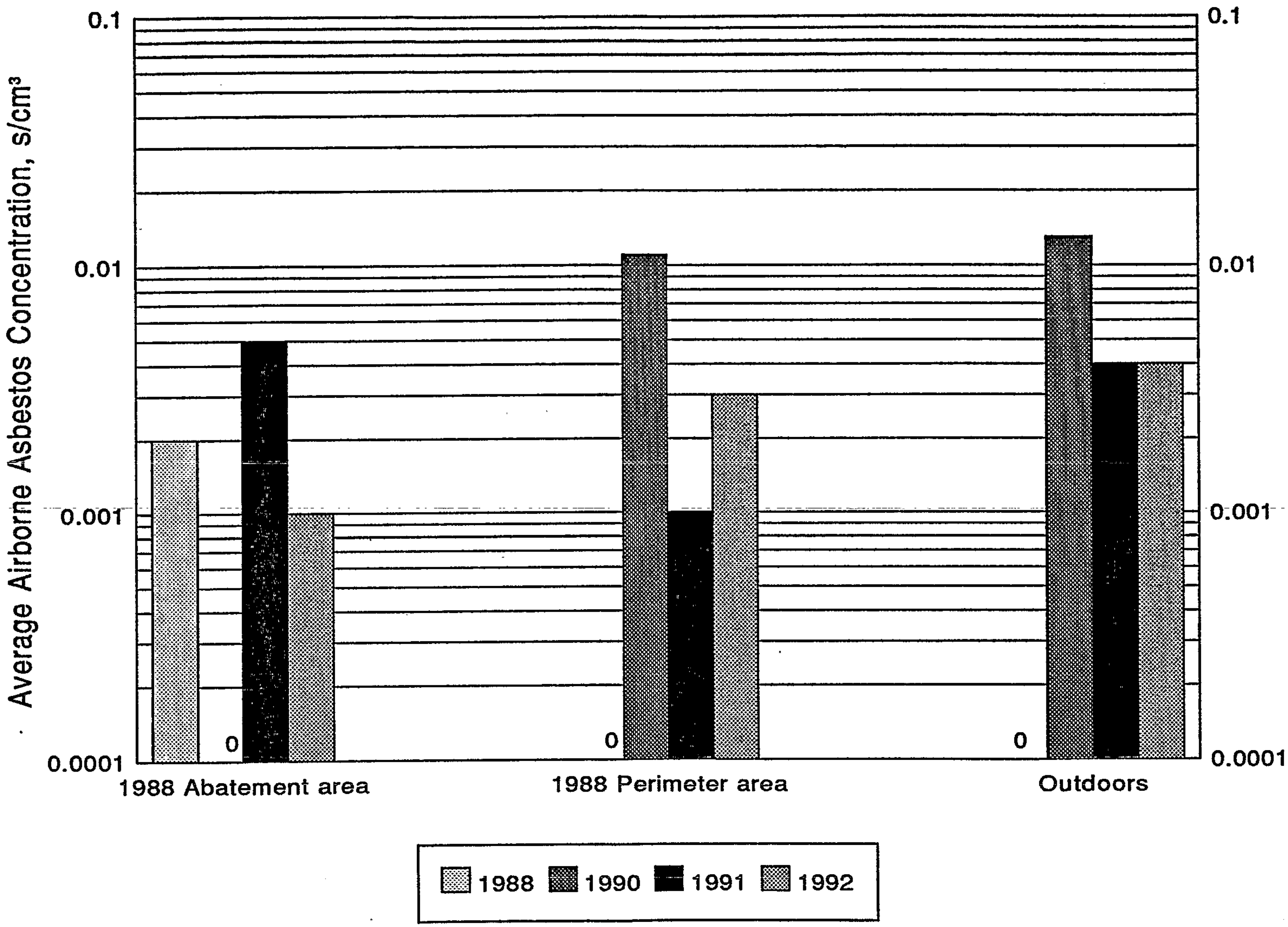

Figure B-18. Average airborne asbestos concentrations measured at Site R.

AHERA initial screening test because the average filter concentration (11 s/mm^2) was below 70 s/mm^2. Furthermore, the site would have passed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. These results are consistent with AST sampling results.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the abatement in 1988 (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.002 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured outdoors (0.013 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.011 s/cm^3) was not significantly different from the average outdoor concentration (0.013 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured in the perimeter area (0.011 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.005 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.004 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.003 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately.

Table B-108 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-108. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE R

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d]
Abatement area	0.0636	1991(0.005) 1988(0.002) 1992(0.001) 1990(0)
Perimeter area	0.0173	1990(0.011) 1992(0.003) 1991(0.001) 1988(0)
Outdoors	0.0391	1990(0.013) 1991(0.004) 1992(0.004) 1988(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

1988 Abatement Area

Differences between average airborne asbestos concentrations measured during occupied conditions in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.005 s/cm^3) and the highest individual concentration (0.010 s/cm^3) were measured during occupied conditions in 1991, 3 years after abatement.

Perimeter

The average airborne asbestos concentrations measured in the perimeter area during simulated occupancy in 1990 was significantly greater than the average concentration measured during the AHERA clearance phase of the 1988 abatement. Other differences between average concentrations measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentrations

(0.011 s/cm^3) and the highest individual concentration (0.027 s/cm^3) were measured during simulated occupancy in 1990, 2 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentrations measured outdoors in 1990 was significantly greater than the average concentration measured during the AHERA clearance phase of the 1988 abatement. Other differences between average concentrations measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.013 s/cm^3) and the highest individual concentration (0.038 s/cm^3) were measured in 1990, two years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-109 presents the distribution of structure type and morphology at each sampling location for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 54 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (75.9 percent), and to a lesser extent, matrices (16.7 percent), clusters (3.7 percent), and bundles (3.7 percent).

Table B-110 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 96.3 percent of the observed asbestos structures were less than 5 µm in length. Of the 41 asbestos fibers observed, only 2 (4.9 percent) were greater than 5 µm in length.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site R as part of the State's traditional quality assurance program, which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Seven visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on top of ventilation ducts, in wall penetrations, on horizontal surfaces, and on pipes, pipe fittings, elbows, and joints throughout the entire containment area. Pipe insulation was also present on counters and floor coverings. The contractor was required to reclean these areas.

TABLE B-109. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE R

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	2	100	0	100	0	0	0
	1990	0	-	-	-	-	-	-
	1991	7	100	0	100	0	0	0
	1992	2	100	0	50	0	50	0
Perimeter area	1988	0	-	-	-	-	-	-
	1990	11	100	0	81.8	0	0	18.2
	1991	2	100	0	100	0	0	0
	1992	6	100	0	50	16.7	0	33.3
Outdoors	1988	0	-	-	-	-	-	-
	1990	12	100	0	58.3	8.3	8.3	25
	1991	6	100	0	83.3	0	0	16.7
	1992	6	100	0	83.3	0	0	16.7

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-110. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE R

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	2	50	100	100	100	100	100
	1990	0	-	-	-	-	-	-
	1991	7	71.4	100	100	100	100	100
	1992	2	100	100	100	100	100	100
Perimeter area	1988	0	-	-	-	-	-	-
	1990	11	9.1	63.4	90.9	90.9	100	100
	1991	2	100	100	100	100	100	100
	1992	6	33.3	66.7	83.3	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	12	0	16.7	66.7	75	91.7	100
	1991	6	100	100	100	100	100	100
	1992	6	83.3	83.3	83.3	83.3	83.3	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

After these areas were recleaned, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of gross debris on ventilation ducts, pipes, pipe hangers, elbows, joints, conduit, and other horizontal surfaces. Residual debris was also found in wall penetrations throughout the containment area. After these areas were recleaned by the contractor, NJDOH conducted a third visual inspection. The site failed the third visual inspection because of debris in wall penetrations and on horizontal surfaces throughout the entire containment area. After these areas were recleaned, NJDOH conducted a fourth visual inspection. The site failed the fourth visual inspection because of debris behind lockers, on pipes, on pipe joints and elbows, on tops of ventilation ducts, and on other horizontal surfaces throughout the entire containment area. After these areas were recleaned, NJDOH conducted a fifth visual inspection. The site failed the fifth visual inspection because of debris on pipes, pipe elbows, and joints; on student lockers; behind counters; and on the floor. After these areas were recleaned by the contractor, NJDOH conducted a sixth visual inspection. The site failed the sixth visual inspection because of debris on ventilation ducts and fans, on floors, on pipe elbows, and on other horizontal surfaces. After these areas were recleaned by the contractor, NJDOH conducted a seventh visual inspection, which the site passed.

1991 Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, on November 7, 1991, a NJDOH Visual Inspection was conducted at Site R as a follow-up. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in November 1991.

1988 Abatement Areas

Corridors and Classrooms--TSI residue (positive for chrysotile asbestos) was collected in the Home Economics Room (Table B-111). Other such residue were noted in the basement corridors. All abatement areas could not be assessed because of the extensive construction activity in the abatement area classrooms. All of the areas examined were coated with an encapsulant.

1988 Perimeter Areas

Central Basement Shops--No debris or material was identified.

Ramp to the Kitchen--Damaged thermal system insulation was found behind a large grille in a wall recession that opens to the abatement area corridor. These materials do not appear in the Asbestos Management Plan.

TABLE B-111. SUMMARY OF BULK RESULTS - SITE R 1991 INSPECTION

Location	Type of Material	Analyses
Home Economics Room	Debris on pipe riser	Positive[a], chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

Kitchen Areas--Thermal system insulation was noted above the suspended ceiling system.

Conclusions

TSI debris was present on a pipe riser in the 1988 abatement area. Damaged TSI was present in the 1988 perimeter areas. This TSI did not appear in the Management Plan and were minor in nature. The heavy use of encapsulants may have contributed to the acceptable air levels of asbestos.

SITE S

Background

Site Description

The abatement project at this two-story school building involved the removal of approximately 7200 ft^2 of trowel-applied, asbestos-containing acoustical ceiling plaster. The abatement area included a gymnasium and stage, corridors, and storage areas. The project specifications indicated that the asbestos content of the acoustical ceiling plaster was approximately 10 to 20 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area, but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter area and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-112 summarizes the results of the five sampling efforts. Figure B-19 shows the mean airborne asbestos concentrations at Site S. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-113 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the abatement in 1988 (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

TABLE B-112. SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE S[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	--	0.001	0	0.005	0.001	0	0.005
Postabatement-1988	0.012	0	0.028	0.003	0	0.008	0	0	0
Simulated occupancy-1990	0.003	0	0.014	0.001	0	0.005	0	0	0
Occupied conditions-1991	0.001	0	0.004	0.003	0	0.011	0.001	0	0.004
Occupied conditions-1992	0	0	0	0.001	0	0.003	0.007[c]	0	0.020

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

[c] N = 4.

TABLE B-113. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE S

Sampling period	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	1.0	P(0.001) O(0.001)
Postabatement-1988	0.0708	A(0.012) P(0.003) O(0)
Simulated occupancy-1990	0.5865	A(0.003) P(0.001) O(0)
Occupied conditions-1991	0.5776	P(0.003) A(0.001) O(0.001)
Occupied conditions-1992	0.0319	O(0.007) P(0.001) A(0)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

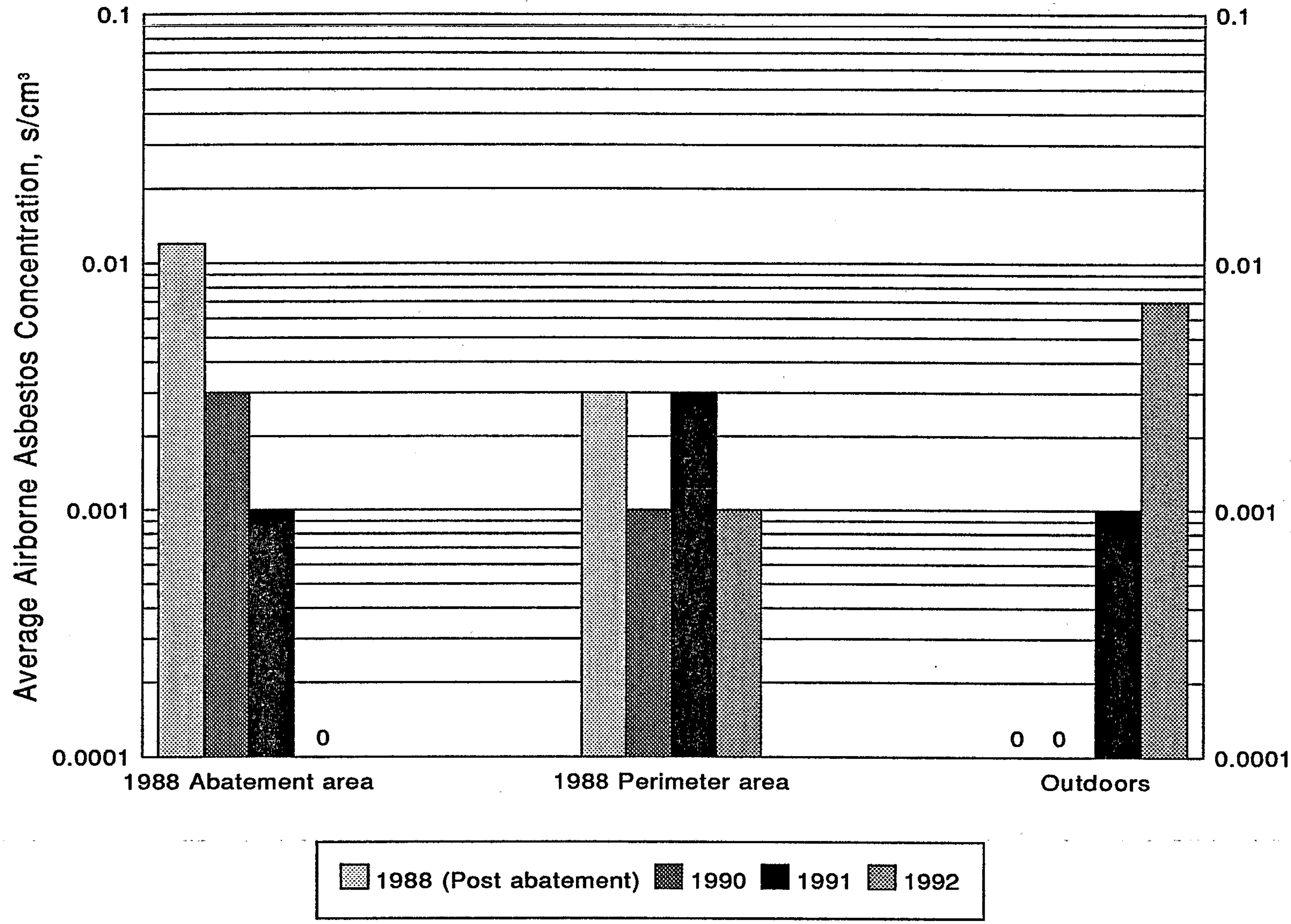

Figure B-19. Average airborne asbestos concentrations measured at Site S.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (82 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test if the abatement area concentrations were compared with the outdoor concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the abatement in 1988 (0.012 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.012 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.003 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.001 s/cm^3) was not significantly different from the average outdoor concentration (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.003 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.003 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured outdoors (0.007 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.007 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-114 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-114. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE S

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0779	1988(0.012) 1990(0.003) 1991(0.001) 1992(0)
Perimeter area	0.6448	1988(0.003) 1991(0.003) 1990(0.001) 1992(0.001) 1988P(0.001)
Outdoors	0.0129	1992(0.007) 1991(0.001) 1988P(0.001) 1988(0) 1990(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement

1988 Abatement Area

Differences between average airborne asbestos concentrations in the abatement area in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.012 s/cm^3) and the highest individual concentration (0.028 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter

Differences between average airborne asbestos concentrations measured in the perimeter area in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.003 s/cm^3) and the highest individual concentration (0.011 s/cm^3) were measured during occupied conditions in 1991, 3 years after the 1988 abatement.

Outdoors

The average airborne asbestos concentration measured outdoors in 1992 was significantly greater than the average concentration measured postabatement in 1988 and in 1990. Differences between average concentrations measured in 1988, 1990, and 1991 were not statistically significant. The highest average concentrations (0.007 s/cm^3) and the highest individual concentration (0.020 s/cm^3) were measured in 1992, four years after the 1988 abatement.

Structure Morphology and Size Distributions

Table B-115 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 42 asbestos structures, all of which were chrysotile asbestos. Overall, the asbestos structures were primarily fibers (71.4 percent), and to a lesser extent, clusters (16.7 percent), matrices (7.1 percent), and bundles (4.8 percent).

Table B-116 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. Overall, 95.2 percent of the observed asbestos structures were less than 5 µm in length. Of the 30 asbestos fibers observed, only 1 (3.3 percent) was greater than 5 µm in length.

TABLE B-115. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE S

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	15	100	0	60	0	33.3	6.7
	1990	3	100	0	66.7	33.3	0	0
	1991	1	100	0	0	0	0	100
	1992	0	-	-	-	-	-	-
Perimeter area	1988	4	100	0	50	25	25	0
	1990	1	100	0	0	0	100	0
	1991	4	100	0	100	0	0	0
	1992	3	100	0	100	0	0	0
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	1	100	0	100	0	0	0
	1992	10	100	0	90	0	0	10

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-116. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE S

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 µm	≤2 µm	≤3 µm	≤4 µm	≤5 µm	≤10 µm
Abatement area	1988	15	20	46.7	80	86.7	93.3	100
	1990	3	66.7	100	100	100	100	100
	1991	1	100	100	100	100	100	100
	1992	0	-	-	-	-	-	-
Perimeter area	1988	4	0	25	75	75	75	100
	1990	1	0	0	0	100	100	100
	1991	4	100	100	100	100	100	100
	1992	3	66.7	100	100	100	100	100
Outdoors	1988	0	-	-	-	-	-	-
	1990	0	-	-	-	-	-	-
	1991	1	100	100	100	100	100	100
	1992	10	80	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site S as part of the State's traditional quality assurance program, which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Three visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on floors, on electrical wires and fixtures, behind floor moldings, behind shelving units, and behind balcony seats. After these areas were recleaned by the abatement contractor, NJDOH conducted a second visual inspection. The site failed the second visual inspection because of the presence of minor debris on the tops of exits signs, skylights, and stage fixtures and dust on the balcony floor and shelving units. After these areas were recleaned by the abatement contractor, NJDOH conducted a third visual inspection, which the site passed.

1991 Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, NJDOH conducted a visual inspection at Site S on November 6, 1991, as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in November 1991.

1988 Abatement Area

Gymnasium--The asbestos-containing ceiling plaster was removed by scraping the material from the browncoat and then hammering the browncoat to break it loose from the supporting wire mesh. This resulted in loose, crumbled browncoat being trapped above the mesh. Such an approach posed a problem of how to remove the material above the supporting wire mesh. This area was not accessible to the workers, but it was now part of the abatement zone. The abatement contractor was allowed to encapsulate the remaining browncoat by spraying through the mesh. In a more conventional approach, the asbestos browncoat and wire mesh would have been removed, which would have allowed the workers to access the upper areas to remove all of the debris. Residue from the asbestos-containing ceiling plaster was noted on several duct inlets (Table B-117). Crumbled browncoat plaster was noted above the supporting wire mesh.

Corridors--As noted for the gymnasium, browncoat plaster was noted above the supporting wire mesh.

1988 Perimeter Areas

Classrooms--Asbestos-containing block pipe insulation (24 percent chrysotile asbestos) was noted in the closet overhead areas (Table B-117). This material was not identified in the Asbestos Management Plan.

Library--Damaged thermal system insulation (elbows) was noted. This material is not identified in the Asbestos Management Plan.

Crawl Space--Damaged cementitious elbows and joints of various homogeneous types (4 to 19 percent chrysotile asbestos) associated with wrapped fiberglass insulation were noted. Air-cell paper insulation matching the description of materials located on the second floor was also noted. The crawl space and these materials do not appear in the Asbestos Management Plan.

Boiler Room by the Gym--Large pieces of elbow debris (22 percent chrysotile asbestos) were found behind the incinerator (Table B-117).

Conclusions

Debris from the ceiling plaster abated in 1988 was present on surfaces in the 1988 abatement area. TSI was present in the 1988 perimeter areas. This TSI did not appear in the Management Plan.

TABLE B-117. SUMMARY OF BULK SAMPLE RESULTS - SITE S 1991 INSPECTION

Location	Type of Material	Analyses
1988 Abatement Areas		
Gym balcony	Residue on vent	Positive[a], chrysotile asbestos
Gym SW wall	Residue at ceiling wall junction	Positive, chrysotile asbestos
1988 Perimeter Areas		
Library	Old ceiling tile at pipe entry	Positive, chrysotile asbestos
Library	Broken joint in corner	Negative
Classroom, middle, east wing	Pipe in closet	24% amosite asbestos
Boiler room by gym	Elbow debris	22% chrysotile
Crawl space	Elbow associated with fiberglass, cloth outer wrap	<1% chrysotile asbestos
Crawl space	Joint associated with fiberglass, cloth outer wrap	4% chrysotile asbestos
Crawl space	2-in. Elbow associated with fiberglass, paper outer wrap	19% chrysotile asbestos
Crawl space	2-in. Joint associated with fiberglass, paper outer wrap	<1% chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

SITE T

Background

Site Description

The abatement project at this three-story school building involved the removal of approximately 4100 ft^2 of spray-applied, asbestos-containing, acoustical ceiling plaster. The abatement area included a cafeteria and stairwell. The project specifications indicated that the asbestos content of the acoustical ceiling plaster was approximately 10 to 25 percent chrysotile. The information regarding the abated ACM and associated asbestos content was obtained from the asbestos abatement specifications for this site.

Air Monitoring Summary

In 1988, postabatement air samples were collected in the abatement area, perimeter area (outside the abatement area, but inside the building), and outdoors at approximately the same time and location as those samples collected by the Asbestos Safety Technician (AST) for the AHERA clearance of the site. Preabatement samples were also collected in the perimeter areas and outdoors before the 1988 abatement activities. Final clearance of the abatement site was based on the samples collected by the AST. In 1990, air samples were collected at this school by use of a modified aggressive sampling technique to simulate occupied conditions. The samples were collected at approximately the same locations as those collected in 1988. In 1991 and 1992, air samples were collected at this school during occupied conditions (i.e., during normal school operating hours) at approximately the same locations as those collected in 1988 and 1990.

Summary of Air Monitoring Results

Table B-118 summarizes the results of the five sampling efforts. Figure B-20 shows illustrates the mean airborne asbestos concentrations at Site T. A single-factor ANOVA was used to compare mean concentrations measured in each of the three sampling locations. Table B-119 presents the results of the ANOVA analysis. The following subsections summarize the pairwise comparisons of the mean concentrations in the three sampling locations.

Preabatement - 1988

The average airborne asbestos concentration measured in the perimeter area before the 1988 abatement (0 s/cm^3) was significantly less than the average concentration measured outdoors (0.003 s/cm^3).

TABLE B-118 SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS (s/cm^3) MEASURED AT SITE T[a]

Sampling period	Abatement area (N=5)			Perimeter area (N=5)			Outdoors (N=5)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Preabatement-1988	-[b]	-	-	0	0	0	0.003	0	0.005
Postabatement-1988	0.049	0.037	0.061	0.030	0	0.070	0.015	0	0.050
Simulated occupancy-1990	0.001	0	0.005	0.001	0	0.005	0.005	0	0.015
Occupied conditions-1991	0.001	0	0.007	0.001	0	0.004	0	0	0
Occupied conditions-1992	0	0	0	0.001	0	0.003	0.001	0	0.003

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] Abatement area was not accessible for preabatement sampling.

TABLE B-119. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED AT SITE T

Year	ANOVA p-value[a]	Statistically significant differences in mean airborne asbestos concentration[b,c,d]
Preabatement-1988	0.04	O(0.003) P(0)
Postabatement-1988	0.0720	A(0.049) P(0.030) O(0.015)
Simulated occupancy-1990	0.2504	O(0.005) A(0.001) P(0.001)
Occupied conditions-1991	0.4214	A(0.001) P(0.001) O(0)
Occupied conditions-1992	0.3349	A(0) P(0.001) O(0.001)

[a] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[b] A = 1988 Abatement area; P = 1988 Perimeter area; O = Outdoors

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that sampling location.

[d] Sampling locations (means) connected by a line are not significantly different.

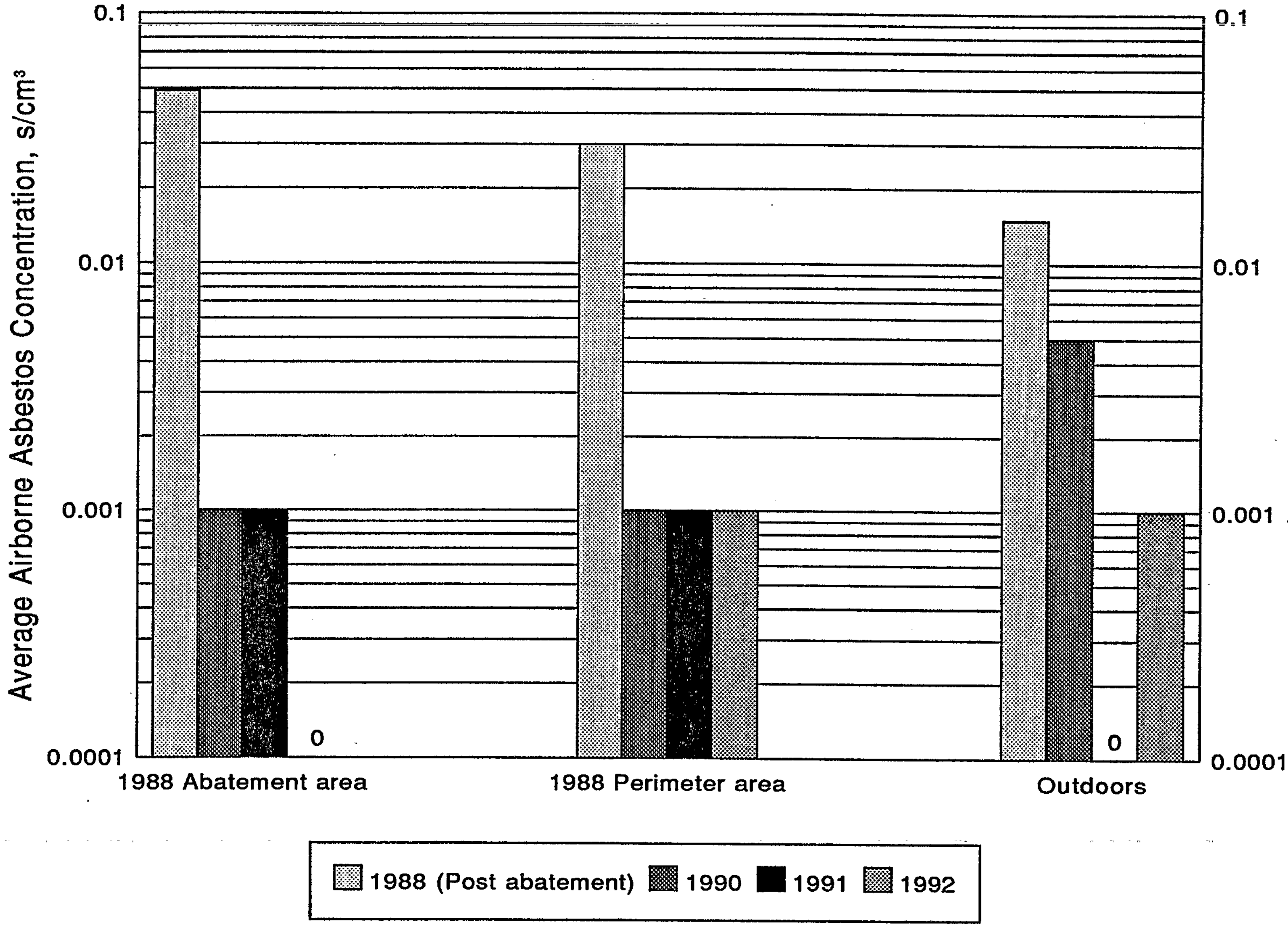

Figure B-20. Average airborne asbestos concentrations measured at Site T.

Postabatement - 1988

AHERA Clearance Test

Airborne asbestos concentrations measured by EPA/NJDOH during the AHERA clearance phase of the 1988 abatement showed that this site would have failed the AHERA initial screening test because the average filter concentration (321 s/mm^2) exceeded 70 s/mm^2. Furthermore, the site would have failed the AHERA Z-test regardless of whether the abatement area concentrations were compared with the outdoor concentrations or with the perimeter concentrations. Although the site ultimately passed AHERA clearance by using the AST sampling results, the EPA/NJDOH results clearly show that elevated levels of airborne asbestos still existed in the school in 1988.

Comparison of the Abatement Area With Outdoors

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.049 s/cm^3) was not significantly different from the average concentration measured outdoors (0.015 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the 1988 abatement (0.030 s/cm^3) was not significantly different from the average concentration measured outdoors (0.015 s/cm^3).

Comparison of the Abatement Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.049 s/cm^3) was not significantly different from the average concentration measured in the perimeter areas (0.030 s/cm^3).

Simulated Occupancy - 1990

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.005 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area in 1990 (0.001 s/cm^3) was not significantly different from the average outdoor concentration (0.005 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 2 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1991

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 3 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Occupied Conditions - 1992

Comparison of the Previously Abated Area With Outdoors

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Perimeter Area With Outdoors

The average airborne asbestos concentration measured in the perimeter area 4 years after the 1988 abatement (0.001 s/cm^3) was not significantly different from the average concentration measured outdoors (0.001 s/cm^3).

Comparison of the Previously Abated Area With the Perimeter Area

The average airborne asbestos concentration measured in the abatement area 4 years after the 1988 abatement (0 s/cm^3) was not significantly different from the average concentration measured in the perimeter area (0.001 s/cm^3).

Comparison of 1988, 1990, 1991, and 1992 Results

A single-factor ANOVA was used to compare mean concentrations measured in 1988, 1990, 1991, and 1992. Each sampling location was evaluated separately. Table B-120 presents the results of the ANOVA analysis, along with the results of the Tukey multiple comparison test. The subsections following the table summarize the pairwise comparisons of mean concentrations measured in 1988, 1990, 1991, and 1992.

TABLE B-120. SUMMARY OF ANOVA RESULTS FOR AIRBORNE ASBESTOS CONCENTRATIONS MEASURED IN 1988, 1990, 1991, AND 1992 AT SITE T

Sampling location[a]	ANOVA p-value[b]	Statistically significant differences in mean airborne asbestos concentration[c,d,e]
Abatement area	0.0001	1988(0.049) 1990(0.001) 1991(0.001) 1992(0)
Perimeter area	0.0011	1988(0.030) 1990(0.001) 1991(0.001) 1992(0.001) 1988P(0)
Outdoors	0.3082	1988(0.015) 1990(0.005) 1988P(0.003) 1992(0.001) 1991(0)

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

[b] If the ANOVA p-value was less than 0.05, the Tukey multiple comparison procedure was then used to distinguish pairwise differences between sampling locations.

[c] Parenthetical entries are mean airborne asbestos concentrations (s/cm^3) associated with that year's monitoring.

[d] Years (means) connected by a line are not significantly different.

[e] 1988P = Preabatement; 1988 = Postabatement.

1988 Abatement Area

The average airborne asbestos concentration measured in the abatement area during the AHERA clearance phase of the 1988 abatement (0.049 s/cm^3) was significantly greater than the average concentrations measured in 1990 (0.001 s/cm^3), 1991 (0.001 s/cm^3) , and 1992 (0 s/cm^3). Differences between average airborne asbestos concentrations measured in the abatement area in 1990, 1991 and 1992 were not statistically significant. The highest average concentration (0.049 s/cm^3) and the highest individual concentration (0.061 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Perimeter Area

The average airborne asbestos concentration measured in the perimeter area during the AHERA clearance phase of the 1988 abatement (0.030 s/cm^3) was significantly greater than the average concentrations measured preabatement in 1988 (0 s/cm^3), in 1990 (0.001 s/cm^3), in 1991 (0.001 s/cm^3), and in 1992 (0.001 s/cm^3). Differences between average airborne asbestos concentrations measured in the abatement area preabatement in 1988, and those measured in 1990, 1991 and 1992 were not statistically significant. The highest average concentration (0.030 s/cm^3) and the highest individual concentration (0.070 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Outdoors

Differences between average concentrations measured in 1988, 1990, 1991, and 1992 were not statistically significant. The highest average concentration (0.015 s/cm^3) and the highest individual concentration (0.050 s/cm^3) were measured during the AHERA clearance phase of the 1988 abatement.

Structure Morphology and Size Distributions

Table B-121 presents the distribution of structure type and morphology at each sampling location separately for each year of monitoring. The TEM analysis of 20 samples collected in the abated area, 20 collected in the perimeter area, and 20 collected outdoors yielded a total of 127 asbestos structures, of which 99.2 percent were chrysotile asbestos and 0.8 percent were amphibole asbestos. Overall, the asbestos structures were primarily fibers (88.2 percent), and to a lesser extent, matrices (11 percent), and bundles (0.8 percent).

Table B-122 presents the cumulative size distribution of asbestos samples at each sampling location separately for each year of monitoring. All of the observed asbestos structures were less than 5 µm in length.

TABLE B-121. DISTRIBUTION OF ASBESTOS STRUCTURE TYPE AND MORPHOLOGY AT SITE T

Sampling location[a]	Year	Number of structures	Type of asbestos		Structure morphology			
			Chrysotile, %	Amphibole, %	Fibers, %	Bundles, %	Clusters, %	Matrices, %
Abatement area	1988	59	100	0	89.8	0	0	10.2
	1990	1	100	0	100	0	0	0
	1991	2	100	0	100	0	0	0
	1992	0	-	-	-	-	-	-
Perimeter area	1988	36	100	0	83.3	0	0	16.7
	1990	1	0	100	100	0	0	0
	1991	2	100	0	100	0	0	0
	1992	1	100	0	100	0	0	0
Outdoors	1988	18	100	0	88.9	5.6	0	5.6
	1990	5	100	0	80	0	0	20
	1991	0	-	-	-	-	-	-
	1992	2	100	0	100	0	0	0

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

TABLE B-122. CUMULATIVE SIZE DISTRIBUTION OF ASBESTOS STRUCTURES MEASURED AT SITE T

Sampling location[a]	Year	Number of structures	Cumulative percentage of asbestos structures					
			≤1 μm	≤2 μm	≤3 μm	≤4 μm	≤5 μm	≤10 μm
Abatement area	1988	59	78	96.6	100	100	100	100
	1990	1	0	0	100	100	100	100
	1991	2	100	100	100	100	100	100
	1992	0	-	-	-	-	-	-
Perimeter area	1988	36	61.1	88.9	97.2	97.2	100	100
	1990	1	0	0	0	0	100	100
	1991	2	50	50	50	50	100	100
	1992	1	100	100	100	100	100	100
Outdoors	1988	18	88.9	100	100	100	100	100
	1990	5	40	100	100	100	100	100
	1991	0	-	-	-	-	-	-
	1992	2	50	100	100	100	100	100

[a] Samples were collected each year in the 1988 abatement and perimeter areas and outdoors.

NJDOH Visual Inspections

1988 Inspection

The NJDOH's Environmental Health Service conducted a final visual inspection at Site S as part of the State's traditional quality assurance program, which provides a check and balance to asbestos abatement to ensure that high-quality abatement and state-of-the art work practices are used. The onsite AST collected the AHERA clearance air samples only after the site had passed the NJDOH visual inspection.

Two visual inspections were required at this site. The site failed the first visual inspection because of the presence of debris on floors, walls, pipes, light fixtures, wall-ceiling junctions, and wall penetrations. After these areas were recleaned by the abatement contractor, NJDOH conducted a second visual inspection, which the site passed.

1991 Inspection

Although asbestos monitoring conducted in May 1991 found airborne levels of asbestos within the AHERA criteria, NJDOH conducted a visual inspection at Site T on October 22, 1991, as a followup. The visual inspection strategy considered the asbestos-abatement history of the site, the O&M activities, and other sources of possible asbestos contamination (i.e., materials not included in the Asbestos Management Plan). Only those areas indicated in the following subsections were examined by the NJDOH inspector in October 1991.

1988 Abatement Areas

Cafeteria--The residual spray-on materials (positive for chrysotile asbestos) were obtained from the ceiling and wall junction as encapsulated "bumps" along the border of the original ceiling application (Table B-123), Loose ceiling debris was also recovered from one pipe hanger. All the pipes in the abatement area have been reinsulated with fiberglass. This negated a thorough inspection of pipe surfaces without removing the fiberglass. All pipe penetrations (wall and ceiling) were foamed or caulked.

The area also has a new suspended ceiling system that isolates the original abatement zone from the occupied space below. Numerous penetrations of the browncoat occurred during the ceiling abatement. Air is moved through the lower, occupied space and into the zone above the suspended ceiling via vents in the wall. The vents lead to ducts that run throughout the facility.

TABLE B-123. SUMMARY OF BULK SAMPLE RESULTS - SITE T 1991 INSPECTION

Location	Type of Material	Analyses
<u>1988 Abatement Areas</u>		
Cafeteria, west wall	Debris in hanger	Positive[a], chrysotile asbestos
Cafeteria, SE wall	Encapsulated residue	4% chrysotile asbestos
Cafeteria, NW wall	Encapsulated residue	Positive, chrysotile asbestos
<u>1988 Perimeter Areas</u>		
Basement hall at custodial office	Encapsulated debris at duct	39% chrysotile asbestos
Basement hall at custodial office	Encapsulated debris at duct	Positive, chrysotile asbestos
2nd-Floor hall	1-ft by 1-ft Ceiling tile	Negative
3rd-Floor hall	1-ft by 1-ft Ceiling tile	Negative
3rd-Floor hall	Sheetrock above ceiling tile	Positive, chrysotile asbestos

[a] This classification was defined by the NJDOH laboratory to accommodate samples for which inadequate material was available to allow a full quantitative evaluation, but were of sufficient size to determine that asbestos was present and to determine the specific type of asbestos. Based on the professional judgment of the analyst, the sample is considered to contain greater than 1 percent asbestos.

1988 Perimeter Areas

Basement Hallway --In 1989, thermal system insulation was removed from the pipes and ductwork in this (and other) basement areas. Encapsulated "lumps" (positive for chrysotile asbestos) were recovered from the wall below the ductwork in this area. The tops of the ducts and the pipe penetrations had been heavily sealed with expanding foam and caulk. Although the use of foam and caulk-type sealants is not a preferred practice, this practice does require that the resilient ACM be managed under an O&M Plan. Pipes had been reinsulated with fiberglass and could not be inspected without the removal of these materials.

Perimeter Corridors--The first and second-floor corridors have asbestos-containing resilient floor tile and 1-ft by 1-ft interlock ceiling tiles that are assumed to be asbestos. According to the Asbestos Management Plan, these are nonfriable miscellaneous materials. In some areas, the ceiling tiles are bowed from water or other damage and are friable. The plenum area above the 1-ft by 1-ft suspended ceiling system is not accounted for in the Management Plan. Visual access to the plenum is limited to holes (damaged areas) in the ceiling system. Ductwork (white-grey fiber type) and corrugated pipe insulation with solid joints and elbows were observed. These materials are not identified in the Asbestos Management Plan.

Boiler Room Vertical Shafts--Pipe insulation was in the shafts that rise from the boiler area. These materials are not mentioned in the Asbestos Management Plan.

Gymnasium--Pipe insulation was noted above the suspended ceiling system in the gym. It could be seen from a hole in the wall of the basement corridor. This material is not mentioned in the Asbestos Management Plan.

Third Floor Corridor--Sheetrock above the suspended ceiling system tested positive for chrysotile asbestos. This material does not appear in the Asbestos Management Plan.

Conclusions

The Asbestos Management Plan was not updated regarding the 1989 abatement.

The Asbestos Management Plan noted nine rooms that had not been inspected during the original AHERA inspection. The Plan does not state whether these areas were ever inspected in accordance with the AHERA requirements.

Although debris and residual materials were recovered from the areas inspected, the use of suspended ceilings isolating the abatement zone, the heavy use of encapsulants, foam and sealant, and the use of fiberglass retrofit materials, have resulted in acceptable levels. This, however, does not eliminate the potential for future disturbances through operations and maintenance activities.