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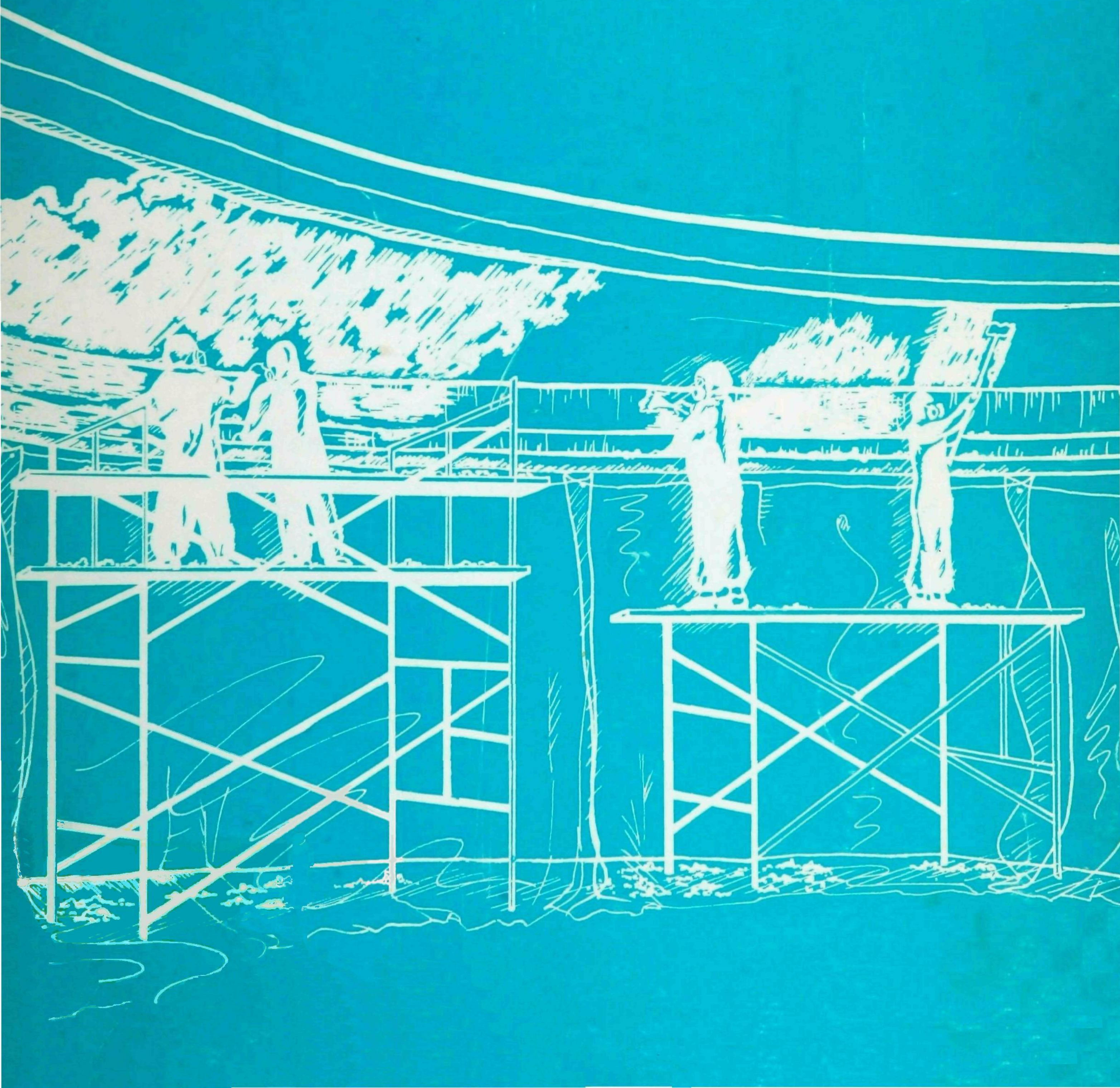
EVALUATION OF ASBESTOS ABATEMENT TECHNIQUES

PHASE I: REMOVAL



October, 1985

EVALUATION OF ASBESTOS ABATEMENT TECHNIQUES
PHASE 1: REMOVAL

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ACKNOWLEDGEMENTS

This study would not have been possible without the cooperation of the local school district. We thank the district officials, school principals, maintenance staff, teachers and students for providing access to their schools and allowing us to collect samples. Wolfgang Brandner of EPA Region VII, and James Trombley of Hoskins-Western-Sonderagger, Inc. also gave valuable assistance. Additional information on Scanning Electron Microscopy was provided by Randi Nordstrom and Gary Casuccio of Energy Technology Consultants and Richard Lee of U.S. Steel.

This was a joint effort by Battelle, Midwest Research Institute, and Research Triangle Institute under contract to the Environmental Protection Agency. The close cooperation among a large number of individuals from all organizations was essential in successfully completing the project.

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency's document, "Friable Asbestos-Containing Materials in Schools, Identification and Notification Rule", as published in May, 1982 in the Federal Register (47 FR 23360), required the identification of friable asbestos-containing materials in schools and the notification of those exposed to the materials. Although there is no requirement to do so, many school districts have decided to undertake an abatement program to reduce the risk of exposure.

In 1983, EPA published "Guidance for Controlling Friable Asbestos-Containing Materials in Buildings" (EPA 560/5-83-002) to help school officials and other building managers deal with asbestos in their buildings. A series of field studies was also initiated to develop quantitative information on the relative merits of alternative abatement methods. The first of these studies, on asbestos removal, is the subject of this report. Information from the field studies and experience gained by EPA and other organizations involved in asbestos control have been incorporated in the 1985 EPA guidance, "Guidance for Controlling Asbestos-Containing Materials in Buildings" (EPA 560/5-85-024). The guidance emphasizes the establishment of a special operations and maintenance (O&M) program whenever asbestos-containing materials are present. The situation is assessed to determine whether additional control action is required, and, if so, which abatement method is appropriate. Abatement methods fall into three main categories:

(1) Removal;
(2) Encapsulation; and
(3) Enclosure.

The appropriate abatement method in a given situation depends on many factors, including the nature of the asbestos-containing material, its condition and accessibility, and the future use of the building.

No matter which abatement method is selected, it is important to be able to measure airborne asbestos levels with sufficient accuracy and precision to determine whether or not an abatement program has been completed satisfactorily. The 1983 EPA guidance document (USEPA 1983a) recommended analysis of air samples by Phase Contrast Microscopy (PCM) for this purpose. PCM is the method that is most familiar, available, and frequently used. It is also the least expensive and has a well-established analytical protocol. However, PCM does not distinquish between asbestos and other types of fibers, and counts only fibers longer than 5 micrometers. Nor is PCM sensitive enough to detect the extremely thin fibers typical of airborne asbestos in buildings. Thus, the interpretation of PCM results assumes that a low concentration of relatively large airborne fibers means that the concentration of asbestos fibers is also low.

Other methods, including Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM), have been proposed as alternatives to PCM, and were discussed at length at a workshop sponsored jointly by EPA and the National Bureau of Standards*. Evidence presented at the workshop, together with the results of this and other studies, has led EPA to recommend TEM when practical constraints such as cost and availability can be overcome (USEPA 1985). EPA acknowledges that all three methods are used in testing for the purpose of releasing abatement contractors. However, only PCM and TEM have standard methods and testing programs. A standard method has not yet been developed for SEM. While TEM is technically the method of choice, PCM is the only option in many localities. EPA is continuing to evaluate the alternatives and update its guidance on appropriate sampling and analysis protocols.

This study, which investigated removal of asbestos-containing material, is Phase 1 of an ongoing program to evaluate alternative abatement techniques. (Phase 2 will investigate encapsulation with latex paint.) The two primary objectives were:

- to compare airborne asbestos levels before, during, and after removal of the asbestos-containing material; and
- to compare analytical methods of assessing airborne asbestos levels.

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* Workshop on the Monitoring and Evaluation of Airborne Asbestos Levels Following an Abatement Program. March 12 and 13, 1984, National Bureau of Standards, Gaithersburg, MD.

A secondary objective was:

- to investigate the relationship between airborne asbestos levels and two properties of the asbestos-containing material, asbestos content and releasability rating index.

The study consisted of five major phases: development of a sampling design, development of a quality assurance plan, field sampling, microscopic analysis of the samples, and statistical analysis.

The sampling design took advantage of a suburban U.S. school district's plan to remove asbestos-containing acoustical plaster from its buildings during the summer of 1983. A total of 24 sites in four schools were selected for air sampling. The sites were made up of 14 sites with asbestos-containing materials on ceilings and walls, 6 indoor sites that did not have asbestos, and 4 outdoor sites. There were four periods of air sampling: (1) before asbestos removal while students were still present; (2) during removal; (3) immediately after removal before the schools reopened; and (4) after school resumed. The same sites were sampled each time with the exception that during removal the asbestos-containing sites were not accessible. During removal, samples were collected immediately outside the barriers separating the work area from the rest of the school.

Samples were collected on both Millipore and Nuclepore filters to permit comparison between different sampling and analytical methods. Bulk samples of the asbestos-containing material were collected prior to the removal operation.

A quality assurance plan was applied to all aspects of the study, including project organization, personnel qualifications, field sampling, sample traceability, sample analysis, data collection and analysis, documentation and reporting. To provide external quality assurance for each method of sample analysis, a proportion of the samples were analyzed by a second laboratory.

Field sampling was carried out according to the sampling design and quality assurance plan. Air samples collected on Millipore filters were analyzed by transmission electron microscopy (TEM) and phase contrast microscopy (PCM). Those collected on Nuclepore filters were analyzed by scanning electron microscopy (SEM). The bulk samples were analyzed by polarized light microscopy (PLM) and rated for their tendency to release asbestos fibers.

Airborne asbestos levels, as measured by TEM, were low (< 6 ng/m^3) both before and after asbestos removal. During removal they were somewhat higher immediately outside the barriers at all 4 schools (up to 140 ng/m^3). The difference is statistically significant at the .01% level. Low levels (up to

1.6 ng/m^3) were observed at outdoor and non-asbestos containing sites during all four sampling periods. (Results are expressed as mass rather than fiber concentrations because TEM detects many small fibers that are not detected by the other methods. TEM fiber concentrations are not equivalent to those obtained by SEM or PCM.) Results obtained by SEM showed a similar pattern to TEM even though asbestos fibers were detected on only 21% of the Nuclepore filters. Total fiber concentrations measured by PCM were highest during the first and fourth sampling periods and did not follow the same trend as the TEM and SEM results.

Analysis of the bulk samples showed that three of the four schools contained similar material (approximately 15 - 25% chrysotile asbestos with releasability rating 4 - 5.5), while the fourth contained materials with a higher asbestos content (84% chrysotile asbestos and releasability ratings up to 7). Releasability is rated on a scale from Ø to 9 with 9 indicating a very strong tendency to release fibers. The fourth school also had the highest average airborne asbestos levels during abatement, although this most likely reflects the inadequacy of the barriers. Negative air pressure systems were not used in any of the schools during the removal operation.

All airborne asbestos levels measured in this study were relatively low and results should be interpreted in that context.

The principal findings of the study are:

- It is possible to achieve low airborne asbestos levels after a removal operation. However, care must be taken to minimize escape of asbestos fibers from the worksite while removal is in progress. Further research is needed on barrier construction and use of negative air systems.

  Evidence: Airborne asbestos levels in asbestos-containing sites were low after asbestos removal (<0.5 ng/m^3). Higher levels (up to 140 ng/m^3) were found immediately outside the containment area while removal was in progress. Even though airborne asbestos levels were low (< 6 ng/m^3) before removal, the elevated levels outside the containment areas indicate that the removal did cause significant fiber release. The low levels after removal show that post-removal cleaning was effective.

- TEM provides the clearest documentation of changes in airborne asbestos levels. PCM measurements appear to be related to the level of human activity rather than to the concentration of asbestos fibers.

  Evidence: The TEM results showed a consistent trend at all four schools, with the highest airborne asbestos levels occurring during removal. Very few fibers were detected by SEM although the results obtained by SEM did follow a similar pattern to those obtained by TEM. Fiber concentrations measured by PCM were low (<Ø.1 f/cc) and showed no relationship to those measured by TEM and SEM. PCM measurements, which include all fiber types, not just asbestos, were highest when students were present and were similar at both asbestos and non-asbestos sites.

- Percent chrysotile content and fiber releasability rating were not useful in predicting airborne asbestos levels before abatement.

Evidence: Pre-abatement air levels were low even at sites with high percent chrysotile and/or releasability ratings. On the other hand, the school with the highest percent chrysotile had the highest mean airborne asbestos levels outside the containment barriers during abatement. This evidence has to be interpreted cautiously because the levels also depend on the effectiveness of the barriers.

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency's document "Friable Asbestos-Containing Materials in Schools, Identification and Notification Rule," as published in May, 1982 in the Federal Register (47 FR 23360), required the identification of friable asbestos-containing materials in schools and the notification of those exposed to the materials. Although there is no requirement to do so, many school districts have decided to undertake an abatement program to reduce the risk of exposure.

In 1983, EPA published "Guidance for Controlling Friable Asbestos-Containing Materials in Buildings" (EPA 560/5-83-002) to help school officials and other building managers deal with asbestos in their buildings. A series of field studies was also initiated to develop quantitative information on the relative merits of alternative abatement methods. The first of these studies, on asbestos removal, is the subject of this report. Information from the field studies, and experience gained by EPA and other organizations involved in asbestos control, have been incorporated in the 1985 EPA guidance, "Guidance for Controlling Asbestos-Containing Materials in Buildings" (EPA 560/5-85-024). The guidance emphasizes the establishment of a special operation and maintenance (O&M) program whenever asbestos-containing materials are present. The situation is assessed to determine whether additional control action is required, and, if so, which abatement method is appropriate. Abatement methods fall into three main categories:

(1) Removal;
(2) Encapsulation; and
(3) Enclosure.

The appropriate abatement method in a given situation depends on many factors, including the nature of the asbestos-containing material, its condition and accessibility, and the future use of the building.

No matter which abatement method is selected, it is important to be able to measure airborne asbestos levels with sufficient accuracy and precision to determine whether or not an abatement program has been completed satisfactorily. The 1983 EPA guidance document (USEPA 1983a) recommended analysis of air samples by Phase Contrast Microscopy (PCM) for this purpose. PCM is the method that is most familiar, available, and frequently used. It is also the least expensive and has a well-established analytical protocol. However, PCM does not distinquish between asbestos and other types of fibers, and counts only fibers longer than 5 micrometers. In addition, is PCM not sensitive enough to detect the extremely thin fibers typical of airborne asbestos in buildings. Thus, the interpretation of PCM results assumes that a low concentration of relatively large airborne fibers means that the concentration of asbestos fibers is also low.

Other methods, including Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM), have been proposed as alternatives to PCM and were discussed at length at a workshop sponsored jointly by EPA and the National Bureau of Standards*. Evidence presented at the workshop, together with the results of this and other studies, has led EPA to recommend TEM when practical constraints such as cost and availability can be overcome (USEPA 1985). EPA acknowledges that all three methods are used in testing for the purpose of releasing abatement contractors. However, only PCM and TEM have standard methods and testing programs. A standard method has not yet been developed for SEM. While TEM is technically the method of choice, PCM is the only option in many localities. EPA is continuing to evaluate the alternatives and update its guidance on appropriate sampling and analysis protocols.

This study, which investigated removal of asbestos-containing acoustical plaster from ceilings and walls, is Phase 1 of an ongoing program to evaluate alternative abatement techniques. (Phase 2 will investigate encapsulation with latex paint.)

Phase 1 had two primary objectives:

- to compare airborne asbestos levels before, during and after asbestos removal; and,

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* Workshop on the Monitoring and Evaluation of Airborne Asbestos Levels Following an Abatement Program. March 12 and 13, 1984, National Bureau of Standards, Gaithersburg, MD.

- to compare analytical methods of assessing airborne asbestos levels.

A secondary objective was:

- to investigate the relationship between airborne asbestos levels and two properties of the asbestos-containing material, asbestos content and releasability rating index.

These objectives were addressed by collecting air and bulk samples at four schools in a suburban school district before, during, and after removal of the asbestos-containing material. The principal conclusions of the study are given in Section 2. Section 3 outlines the quality assurance plan and Section 4 describes the sampling plan. These sections are followed by an account of the field survey (Section 5) and the methods of sample analysis (Section 6). The results of the statistical analyses are given in Section 7.

The Appendices, A-E, contain the excerpts from the QA plan, field sampling and sample analysis protocols, results of the sample analyses and raw data listings.

SECTION 2

CONCLUSIONS

The principal conclusions from this study are listed below under each study objective. All airborne asbestos levels measured in this study were relatively low and the results should be interpreted in that context.

Objective 1

Comparison of airborne asbestos levels before, during and after asbestos removal.

Conclusion: It is possible to achieve low airborne asbestos levels after a removal operation. However, care must be taken to minimize escape of asbestos fibers from the worksite while removal is in progress. Further research is needed on barrier construction, use of negative air systems, etc.

Evidence: Airborne asbestos levels in asbestos-containing sites were low after asbestos removal (< 0.5 ng/m^3). Higher levels (up to 140 ng/m^3) were found immediately outside the containment area while removal was in progress. (Results are expressed as mass rather than fiber concentrations because TEM detects many small fibers that are not detected by the other methods. TEM fiber concentrations are not equivalent to those obtained by SEM or PCM.) Even though airborne asbestos levels were low ($< 6\ ng/m^3$) before removal, the elevated levels outside the containment areas indicate that the removal did cause significant fiber release. The low levels after removal show that post-removal cleaning was effective.

<u>Objective 2</u>

Comparison of methods of assessing airborne asbestos levels.

Conclusion: TEM provides the clearest documentation of changes in airborne asbestos levels. PCM measurements appear to be related to the level of human activity rather than to the concentration of asbestos fibers.

Evidence: The TEM results showed a consistent trend at all four schools, with the highest airborne asbestos levels occurring during removal. Very few fibers were detected by SEM although the results obtained by SEM did follow a similar pattern to those obtained by TEM. Fiber concentrations measured by PCM were low (<0.1 f/cc) and showed no relationship to those measured by TEM and SEM. PCM measurments, which include all fiber types, not just asbestos, were highest when students were present and were similar at both asbestos and non-asbestos sites.

Secondary Objective

Relationship between air levels and properties of the asbestos-containing material.

Conclusion: Percent chrysotile content and fiber releasability rating were not useful in predicting airborne asbestos levels before abatement. However, these bulk material properties may have influenced air levels during abatement.

Evidence: Pre-abatement air levels were low even at sites with high percent chrysotile and/or releasability ratings. On the other hand, the school with the highest percent chrysotile had the highest mean airborne asbestos levels outside the containment barriers during abatement. This evidence has to be interpreted cautiously because the levels also depend on the effectiveness of the barriers.

SECTION 3

QUALITY ASSURANCE

This study was carried out according to a Quality Assurance Plan* which addresses all aspects of the study, including project organization, personnel qualifications, field sampling, sample traceability, sample analysis, data collection and analysis, documentation and reporting. Some of the major components of this plan are summarized below.

The plan describes the project and defines the project organization in terms of the roles and responsibilities of the members. It states how information is communicated within and between organizations, and how progress is reviewed and reported. The quality assurance objectives are described in terms of accuracy, precision, representativeness and completeness.

The QA plan also specifies the number of schools and sites within each school, the number of pumps per site, and the sampling duration for each pump. Additional sections outline personnel qualifications, facilities and equipment, preventive maintenance procedures and schedules, consumables and supplies,

* Evaluation of Asbestos Abatement Techniques, Phase 1, Quality Assurance Plan, submitted to EPA August 2, 1983, Contract 68-Ø1-6721.

documentation, document control, configuration control, sample collection and sample custody.

Detailed guidelines are given for air and bulk sample handling and analysis. The number of field blanks and laboratory blanks and the number of samples to be analyzed in replicate, duplicate and by an independent laboratory are specified for each analytical method. These figures are based on the number and types of samples to be collected. The results of these QA analyses are presented in Section 6.

The remaining sections of the plan give specifics on calibration procedures and reference materials, data validation, data processing and analysis, internal quality control checks, data assessment procedures, feedback and corrective action, quality assurance reports to management, and report design. Appendix A contains excerpts from this QA Plan.

The primary means for external monitoring of the project was provided by a series of performance and systems audits at a rate of one audit per sampling period. These audits were conducted on site to determine and establish sample and data traceability and to determine if sampling and analysis protocols were followed by field personnel. Flow rates were measured on all pumps. Only two of 55 readings exceeded the limits for relative accuracy of ±10% (-10.12% and 11.75%). The average relative accuracy was 2.7% (standard deviation of 2.5%). Some minor problems or inconsistencies were detected during on-site logbook examinations and immediate corrective action was taken.

The initial study design (See Section 4) specified that a total of 276 Millipore filters were to be collected (96 field blanks, 84 3-day filters, and 96 5-day filters). A total of 243 Millipore filters, or 88%, were actually collected; 85 field blanks (89%), 77 3-day filters (92%), and 81 5-day filters (84%). The discrepancy between the planned and actual number of filters was mainly due to loss of sites (due to various reasons including vandalism), unavailability of sites during specific sampling periods, and to nonrecovery of a few filters by field personnel.

Of the 243 Millipore filters collected, a small number (6 or 2.5%) were invalid due to either technical difficulties in the field (plugged flow control orifices resulting in unknown volumes of sampled air), or to bad weather conditions for outdoor filters. Thus, a high percentage (86% or 237 out of 276) of the Millipore filters specified in the QA plan were suitable for analysis.

Eighty-eight Nuclepore filters were initially planned to be collected (76 5-days filters and 12 field blanks). A total of 83 filters were actually collected (69 5-day filters (or 90%) and 14 field blanks.) For each sampling period, 3 Nuclepore field blanks were requested; however, only one was collected during the first sampling period because too few filters were shipped. In later periods, up to 6 field blanks were collected. Of the 69 5-day filters, 4 were invalid, one due to technical field difficulties, and the remaining 3 outdoor filters due to heavy rains. A total of 65 5-day Nuclepore filters, or 86% were available for SEM analysis.

Bulk samples were collected as requested immediately after the first sampling period and all samples were of good quality.

SECTION 4

SAMPLING DESIGN

This study was conducted in conjunction with the asbestos removal program being undertaken in a suburban school system. Schools, and sites within schools, were selected within the constraints of program scheduling and physical accessibility, in order to achieve the study objectives. Three types of sites were identified in each of four schools: sites (rooms) with asbestos-containing material on ceilings and walls that was scheduled for removal, sites without asbestos material, and outdoor sites located on the roofs of the buildings. (A non-asbestos site was not available in the fourth school.)

The first objective was to compare airborne asbestos levels before, during and after asbestos removal. Four periods of air sampling were carried out:

(1) Before removal while students were still at school;

(2) During removal;

(3) Immediately after removal, before school resumed; and,

(4) Five months after removal, with students present.

The same sites were sampled each time with one exception. During the removal operation the asbestos-containing sites were not accessible and samples were collected as close as possible to the original sites, but outside the barriers separating the work area from the rest of the building. The final sampling period was carried out after school had resumed, to determine whether asbestos fibers that might have settled onto the floor or other surfaces throughout the building would be resuspended by the increased activity in the building. This design allowed comparisons among sampling periods at a given site and among sites within a single sampling period. The outdoor sites acted as one type of control since they should not have been affected by conditions within the building. The nonasbestos sites acted as a second type of control since their airborne asbestos levels should have remained relatively constant unless there was rapid transport of fibers throughout the building.

The second objective was to compare methods of assessing airborne levels. Up to three air samples were collected simultaneously at each site. One sample was collected on a Nuclepore filter and subsequently analyzed by SEM. A second sample was collected on a Millipore filter and subsequently analyzed by both TEM and PCM. Both of these samples were collected over 5 working days. At sites where a third sampler was available, a 3-day sample was collected on a Millipore filter to compare lengths of sampling periods. This design allowed direct comparison between TEM and PCM using the same set of samples (filters), and between TEM, PCM and SEM using samples taken simultaneously at the same site.

Bulk samples were collected at each site to characterize the sites and to see if there was any relationship between the nature of the asbestos-containing material and airborne asbestos levels. Two properties of the asbestos-containing material were examined: asbestos content and fiber releasability.

The sampling plan is summarized in Table 1. The number of samples of each type was chosen to ensure sufficient power to detect differences of interest while remaining within constraints imposed by budget and other resources. Insufficient Nuclepore filters were available for use at all sites. Assuming a coefficient of variation of 150% for TEM analysis of air samples, the number of asbestos sites is sufficient to detect a ten-fold difference in airborne asbestos levels between one period and another with a probability of more than 99%. A five-fold difference will be detected with a probability of more than 95% (Chesson et al. 1985).

Table 1. Sampling Plan

School	Site*	Air samples† 3 Day	Air samples† 5 Day	Bulk‡ samples
1	1. Non-asbestos	M	M/N	--
	2. Asbestos	M	M/N	8
	3. Asbestos	M	M/N	8
	4. Non-asbestos	M	M	--
	5. Asbestos	M	M/N	8
	6. Asbestos	M	M/N	8
	7. Outdoor	--	M/N	--
	8. Asbestos	--	---	8
	9. Outside Barrier	M	M/N	--
	10. Outside Barrier	M	M/N	--
2	1. Non-asbestos	M	M	--
	2. Asbestos	M	M/N	8
	3. Non-asbestos	M	M/N	--
	4. Asbestos	M	M/N	8
	5. Asbestos	M	M/N	8
	6. Asbestos	M	M/N	8
	7. Outdoor	--	M/N	--
	8. Outside Barrier	M	M/N	--
	9. Outside Barrier	M	M/N	--
	10. Outside Barrier	M	M/N	--
	11. Outside Barrier	M	M/N	--
3	1. Asbestos	M	M/N	8
	2. Non-asbestos	M	M/N	--
	3. Asbestos	M	M/N	8
	4. Asbestos	M	M/N	8
	5. Non-asbestos	M	M/N	--
	6. Asbestos	M	M/N	8
	7. Outdoor	M	M/N	--
	8. Outside Barrier	M	M/N	--
	9. Outside Barrier	M	M/N	--
	10. Outside Barrier	M	M/N	--
4	1. Asbestos	M	M	8
	2. Asbestos	M	M	8
	3. Outdoor	M	M	--
	4. Outside Barrier	M	M/N	--
	5. Outside Barrier	M	M/N	--
	6. Outside Barrier	M	M/N	--

*Sites located outside the barrier were only sampled while the removal operation was in progress. Asbestos sites were not sampled during removal.

†M = Millipore, N = Nuclepore.

±Six locations per site with a pair of side by side samples at 2 of the 6 locations.

SECTION 5

FIELD SURVEY

I. INTRODUCTION

The field survey included air sampling and bulk sampling. The air sampling took place during four periods in 1983: May 23 through May 27, July 11 through July 22, August 16 through August 20, and November 7 through November 11. The bulk sampling activity took place on June 3, 1983. Battelle Columbus Laboratories (BCL), Midwest Research Institute (MRI), and EPA selected the sites to be surveyed. The statistical basis for the field survey plan is described in Section 4. The protocols that were followed for air sampling and bulk sampling can be found in Appendix B. The protocols are adaptations of those used during a previous study reported in EPA 560/5-83-003 (USEPA 1983b).

II. AIR SAMPLING

Initially, 14 indoor sites in which asbestos-containing material was present were selected for air sampling in the four study schools. Two sites were removed from the program at the request of the teachers, leaving 12 indoor asbestos sites for air sampling. Twelve additional sites were selected which were located just outside of the containment barriers enclosing the asbestos-containing sites sampled during the first sampling period. These 12 sites were sampled only during the active abatement period.

The field survey plan called for the collection at each school of (a) one outdoor ambient air sample, (b) one or two indoor control air samples at sites (rooms) where no asbestos was present, and (c) up to four samples from rooms containing asbestos. All samples at any given school were to be collected simultaneously. Outdoor sites were sampled for 5 days. Two 5-day side-by-side samples were collected at indoor sites, one using a Nuclepore and the other using a mixed cellulose ester membrane (Millipore) filter. At some indoor sites a 3-day sample was collected on a second Millipore filter.

While school was in session, samples were collected at each site during school hours. While school was out, sample collection, during and after abatement, took place during the same hours students would normally have been in the classrooms.

The sampling rate was to be approximately 5 l/min, for a total volume of air sampled of approximately 6 m^3 for 3-day samples and 10 m^3 for 5-day samples.

A. <u>Sampling System</u>

The air sampling systems used were of two types. A single filter system was used for the 3-day samples, as shown in Figure 1. A double filter system was used for the 5-day side-by-side samples and consisted of the same system as shown in the figure, but equipped with two orifices. One orifice controlled

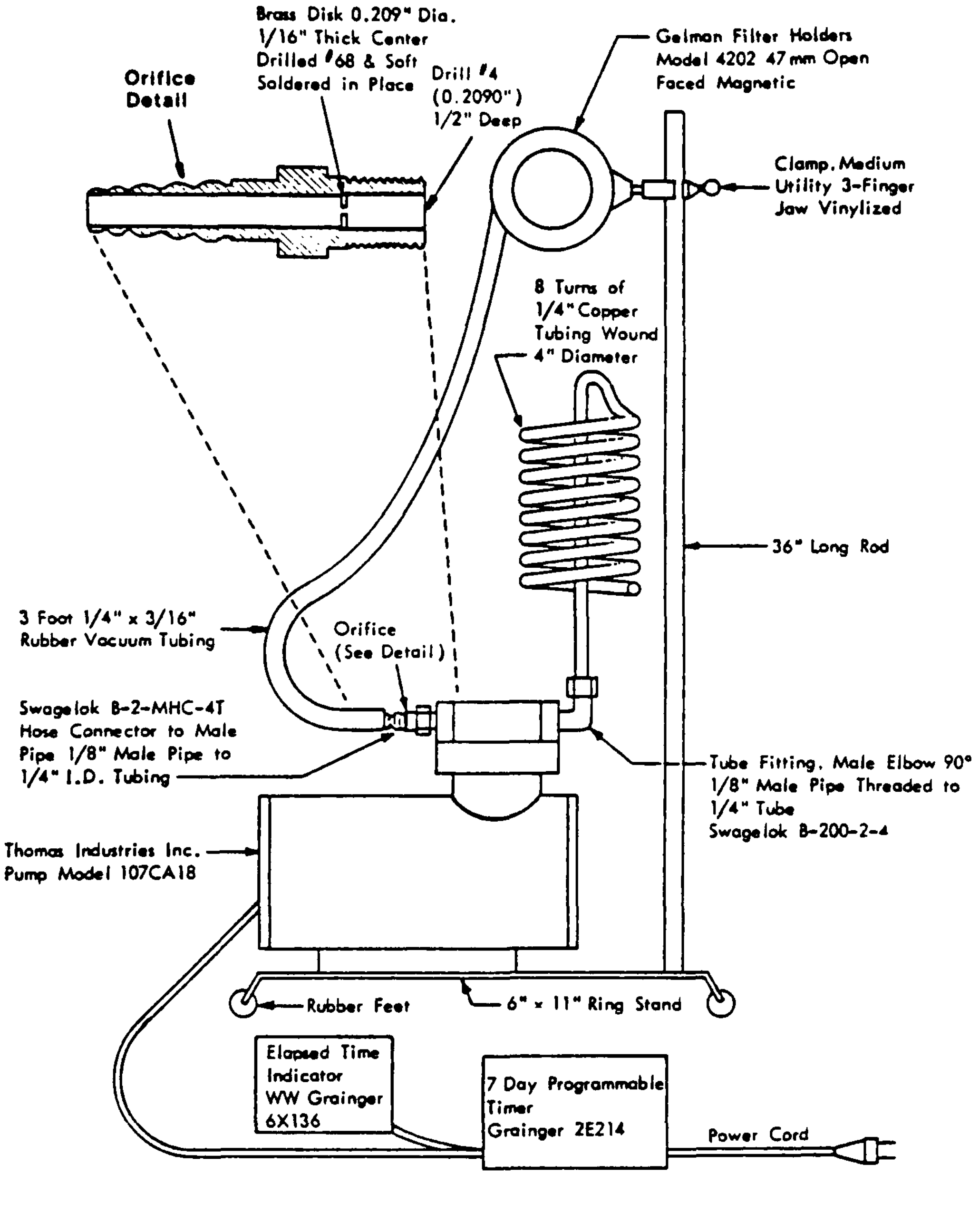

Figure 1. Air sampling system.

the flow through a 47 mm filter holder containing a Ø.45 m Millipore filter. The second orifice controlled the flow through a 37 mm Millipore two-piece styrene filter holder (MØØØ-37-OW) which contained the Ø.2 m Nuclepore filter. The orifices for the double filter system were drilled (No. 64 standard drill bit, Ø.Ø36" diameter), and were not operated in the critical flow range. A programmable timer was set to start the systems at the beginning of the class day and to stop at the end of the class day. A sampling day ran from 8:ØØ a.m. to 3:3Ø p.m. for a total of 7.5 hrs/day and 37.5 hrs for 5 days. At some of the sampling sites during the abatement phase and immediately after abatement, five test days were not available. In those cases, the test day was extended to obtain a total of 37.5 hrs of sampling.

B. Field Operations

Air sampling was started simultaneously at the four schools in accordance with the sampling protocol presented in Appendix B-1. During field operations some samples were lost and some were collected for an inadequate or unknown length of time. (See Section 3.) These deficient samples resulted from filters being vandalized, power interruptions, field crew errors and, in the case of outdoor samples, the weather.

In an effort to obtain satisfactory samples for as many sites as possible, samples were re-collected when possible. Because of the limited time available before the end of a sampling period, however, not all deficient samples could be re-collected.

Each field team member (referred to as "operator" in the protocol) was given a hardbound logbook for recording data. Most types of data collected are given in the sampling protocol document (Appendix B-1). Additional items recorded include type and operation of air conditioners, room ventilation and occupancy, floor covering, and method and frequency of cleaning.

Because of the number of problems that developed in keeping the sites operational during the sampling period, a walk-through procedure was instituted. This procedure consisted of walking through each school and observing each system. As problems with a system developed, corrective action was taken, including replugging in power cords, resetting timers, replacing malfunctioning equipment, cleaning orifices, and reconnecting hoses. If filters were damaged early in the sampling period, new filters were installed and the unit was restarted. The walk-through period was also used to gather and document information required by the protocol (Appendix B-1) as well as to make other observations.

C. Sample Handling

The air samples were handled according to the protocol (Appendix B-1). Each sample was labeled as it was recovered using an assigned letter followed by a sample number. The sample numbers were assigned sequentially by each operator. At this time, the operator entered the sample number in the logbook for that collection site. Before leaving the site, the operator completed a sample traceability form.

III. BULK SAMPLING

Eight bulk samples were collected from each of 15 indoor asbestos-containing sites. Fourteen of the bulk sampling sites were also air sampling sites. Samples were collected from six randomly selected points at each site. From two of the six points, a double sample was taken side-by-side to provide for replicate and external QA samples. The procedures specified in USEPA 1980 were followed.

A. Sample Selection

Sampling points were designated as a fraction of the room length and width. The field sampling team located a sampling point by measuring the room and converting the fractional value to a unit measure. If a sampling point could not be reached because of its location (for example, above a light fixture or other obstruction), an alternate site was selected from a list of alternates.

B. Sample Collection

Bulk samples were collected by cutting away a section of the asbestos-containing material. A section of material 3 cm in diameter and the thickness of the covering was collected. The collected samples were placed directly into labeled, snap-covered plastic bottles for transport to MRI. At the same time, the operator prepared traceability forms and entered the sample number and site description in the logbook.

C. Sample Handling

The bulk samples were transported to MRI and released to MRI analysts. The MRI quality assurance representative identified the duplicates and selected the samples to be analyzed in replicate, duplicate and by an external QA laboratory. Further details of the bulk sampling procedure can be found in the sampling protocol in Appendix B-2.

IV. TRACEABILITY

The protocol used for establishing traceability of air and bulk samples is given in Appendix B-3. As stated in Section II, after sampling was completed, the samples were transported to MRI and stored. Responsibility for the air samples was transferred at MRI to a BCL representative. The samples and copies of the traceability logs were then hand-carried by the BCL representative to BCL for analysis. The bulk samples and copies of the associated traceability logs were transferred to the MRI analyst at MRI.

V. ABATEMENT TECHNIQUES

The removal program was instigated by the school district and was entirely under its control. Through the cooperation of the school authorities, EPA was able to carry out this study, but did not determine the removal techniques used, nor the timing of them. A copy of contractor specifications for the removal is provided in Appendix B-7. Additional information noted by the field crew is also included in Appendix B-7.

SECTION 6

SAMPLE ANALYSIS

Four types of analyses were performed. Air samples on Millipore filters were analyzed by TEM and PCM. Air samples on Nuclepore filters were analyzed by SEM. Bulk samples were analyzed by polarized light microscopy (PLM). TEM and PCM analyses were done by BCL, SEM analyses were done by Energy Technology Consultants (ETC), and PLM analyses were done by MRI. External quality assurance was provided by EMS Laboratories for TEM, PCM and SEM and by Environmental Health Laboratory for PLM.

I. AIR SAMPLES

For all three methods of analysis, a fiber was defined as a particle with an aspect ratio (length: width) of 3:1 or greater and having parallel sides.

A. Transmission Electron Microscopy (TEM)

A total of 185 analyses (including 26 duplicates and 26* replicates) were done by TEM. A computer listing of the results appears in Appendix C-1.

1. Methods

The filters were coded so that the analyst did not know where the samples were taken or which samples were field blanks.

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*An additional 27th, but invalid, filter was mistakenly analyzed in replicate.

Four analysts performed the analyses on the transmission electron microscope. A senior analyst was always available for consultation in the event of a question about the identification of a fiber or particle. The microscopic examination of the prepared grids was carried out at a magnification of 20,000X. Each grid opening to be counted was selected randomly and then systematically scanned to cover the full opening. The fibers observed were identified as chrysotile, amphibole, or other.

The length and width of the chrysotile and amphibole fibers were recorded. The fiber length was measured using the number of concentric circles on the viewing screen that the fiber crossed (each circle segment was 0.25 μm at 20,000X). The fiber was aligned with the millimeter scale on the side of the viewing screen and the width measured in millimeters (1 mm = 0.05 μm at 20,000X). The volume of the fiber was then computed assuming the fiber to be a right circular cylinder. The mass of the fiber was calculated using a density of 2.6 g/cm^3 for the chrysotile and 3.0 g/cm^3 for the amphibole. Appropriate filter area factors and dilution factors were used to extrapolate from the fibers actually counted and measured to the total number of fibers per filter and total nanograms of asbestos per filter.

The minimum fiber size easily detected at 20,000X during the scanning for the counting procedure is about 0.125 μm long by 0.025 μm in diameter. Since the chrysotile fiber becomes cylindrical by rolling up the silica/brucite sheet, 0.025 µm is about the minimum diameter that will hold together. The minimum diameter detected during this study was 0.025 µm. The maximum fiber size would be one that overlaps the 90 µm grid opening. The largest bundle observed during this study was 2 µm in diameter.

The detection limit for this type analysis is one fiber observed while 10 grid openings are scanned. The protocol calls for the counting of 100 fibers or 10 grid openings whichever occurs first, but never any partial grid openings. One fiber observed in 10 grid openings would correspond to 4×10^3 fibers per filter when the extrapolation is made to total filter area. If the one fiber were of average dimensions (1 µm long x 0.05 µm in diameter), the mass would be 2×10^{-11} g per filter. Since most of the air volumes per sample were approximately 10 m^3, the minimum detectable quantities would be 2×10^{-12} g/m^3 or 0.002 ng/m^3.

The large amount of debris (non-asbestos organic matter) collected on many of the filters made the low temperature ashing procedure a necessity. After ashing, the residue containing the asbestos fibers was resuspended in 100 ml of water using the ultrasonic bath to ensure that the fibers were removed from the ashing tube walls. The resuspended sample was then divided into 10-ml, 20-ml, and 70-ml aliquots, and each aliquot was filtered onto a Nuclepore filter. The three aliquots gave the analyst some flexibility in finding a suitable fiber loading for TEM examination. The protocol for TEM is given in Appendix B-5.

2. Discussion

Fiber bundles and fiber clusters required special attention. A bundle is defined as a group of fibers bound together that make the determination of its constituents difficult. Often it was possible to identify one end of a fiber, but it was not always possible to positively identify all the constituents. A cluster is defined as several overlapping and cross-linked individual fibers. Fibers in a cluster that could be seen as individual fibers were counted as individual fibers, but when the individual fibers could not be distinguished, they were considered a cluster and recorded as such, but not counted.

The way in which bundles and clusters are handled can greatly affect the quantity of asbestos calculated for each filter. Bundles and clusters were not included in the calculation primarily because the analyst could not be sure of uniform distribution or rely on the volume calculations associated with the bundles and clusters. Thus, airborne asbestos levels are underestimated for samples with bundles and clusters. There were 36 5-day samples that had some bundles or clusters (Table 2). (The 3-day samples are not included in this table because only of a few 3-day samples were analyzed and subsequent statistical analyses was based on the 5-day samples

Table 2. The Number of Chrysotile Bundles and Clusters Observed on the Filters but Not Used in the Mass Calculations

Sampling Period	Site Type	Filter ID (total number of bundles and clusters)*
		5-Day Samples
Before Removal	Asbestos	M18(1), M22(2), S21(3), S22(2), S23(9), S27(1), S28(5)
	Non-Asbestos	M21(4), M23(2), S20(8)
During Removal	Asbestos	B2(7), G6(11), G7(10), G14(2+1), G15(7), K13B(6+1), K15(5+13), K23(3+2), K24(3+17)
	Non-Asbestos	B1(4), K7(1) K12B(1), K14(4+1)
	Outdoor	B9(1)
Immediately After Removal	Asbestos	DG20(1)
After School Resumed	Asbestos	D23(1+1), D25(2), D29(2), L22(4), L23(2), L27(3), L30(18)
	Non-Asbestos	L25(1), L29(1)
	Outdoor	D21(1), D32(1)

*The first number following the filter ID refers to the number of bundles and clusters found on duplicate analyses and the second for replicate analyses on the same filter.

only.) Three of these were outdoor ambient samples and 9 were indoor samples at sites without asbestos-containing material. The remaining 24 were samples from sites with asbestos-containing material.

The samples with higher asbestos concentrations tended to have more bundles and clusters. The bundles and clusters were observed on the TEM-prepared filter and must have been deposited as such on the filter during air sampling. The ultrasonification procedure that followed the low temperature ashing tended to break up the fiber bundles and clusters. The primary purpose of sonification was to ensure the removal of fibers from the glass test tube in which the ashing took place. All samples were subjected to the same low temperature ashing and sonification procedure, done according to the protocol; therefore, the effect is assumed to be the same for each sample.

A more accurate mass determination could be made if the ultrasonic procedure were made severe enough to break up all bundles and clusters. However this would make fiber size distribution meaningless.

3. Quality Assurance

Although the TEM protocol (Appendix B-5) is accepted and used by expert microscopists, there are factors that contribute to the possibility of having relatively large variabilities in results. These factors include (a) the presence of agglomerates of asbestos fiber (bundles and clusters) that are not included in the fiber count, since the number of fibers cannot be ascertained, (b) the possible loss or gain of fibers from filters, (c) the effectiveness of the dispersion of fibers during the sonication process, and (d) the production of a nonuniform deposit of the fibers during the filtration operation.

The quality assurance aspect of the analytical part of this program is summarized in the following paragraphs. Besides the standard analyses performed at BCL, three additional types of analyses were done: duplicate, replicate, and external QA analyses.

Duplicate analyses were conducted by a second analyst using the same grid preparations as the first analyst. Replicate analyses were performed using two independent preparations from the same filter. External QA samples were randomly selected for analysis by EMS Laboratories (external QA laboratory). The selected filters were divided at BCL, and one-half of each filter was hand-carried to EMS Laboratories for analysis. The side of the filter to which the fibers adhered was kept upright at all times.

Of the 132 filters to be analyzed by TEM, 26 (six 3-day and twenty 5-day filters) were selected for duplicate, 26* (six 3-day and twenty 5-day filters) were selected for replicate, and

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* An additional 27th, but invalid, filter was mistakenly analyzed in replicate.

28 (eight 3-day and twenty 5-day filters) were chosen for external QA analysis. Fiber counts, fiber concentrations (fibers/m^3), and mass concentrations (ng/m^3) for duplicate, replicate, and QA analysis are shown, side-by-side with the corresponding standard analysis results (Appendix C-4).

Only fiber concentrations and mass concentrations were statistically evaluated. The number of fibers measured under the microscope depends on the area of filter examined and direct comparisons between samples cannot be made for this variable.

For each pair of duplicate, replicate, and external QA analyses, the coefficient of variation (CV: standard deviation/ mean) was calculated and plotted against the mean (for fiber and mass concentration; Figures 2, 3, 4 and 5). When one of the two data points used in the calculation is zero, the CV will always be 141%. The variability for fiber concentrations in the duplicate, replicate, and external QA samples was similar and ranged from Ø to 141% (Figures 2 and 3).

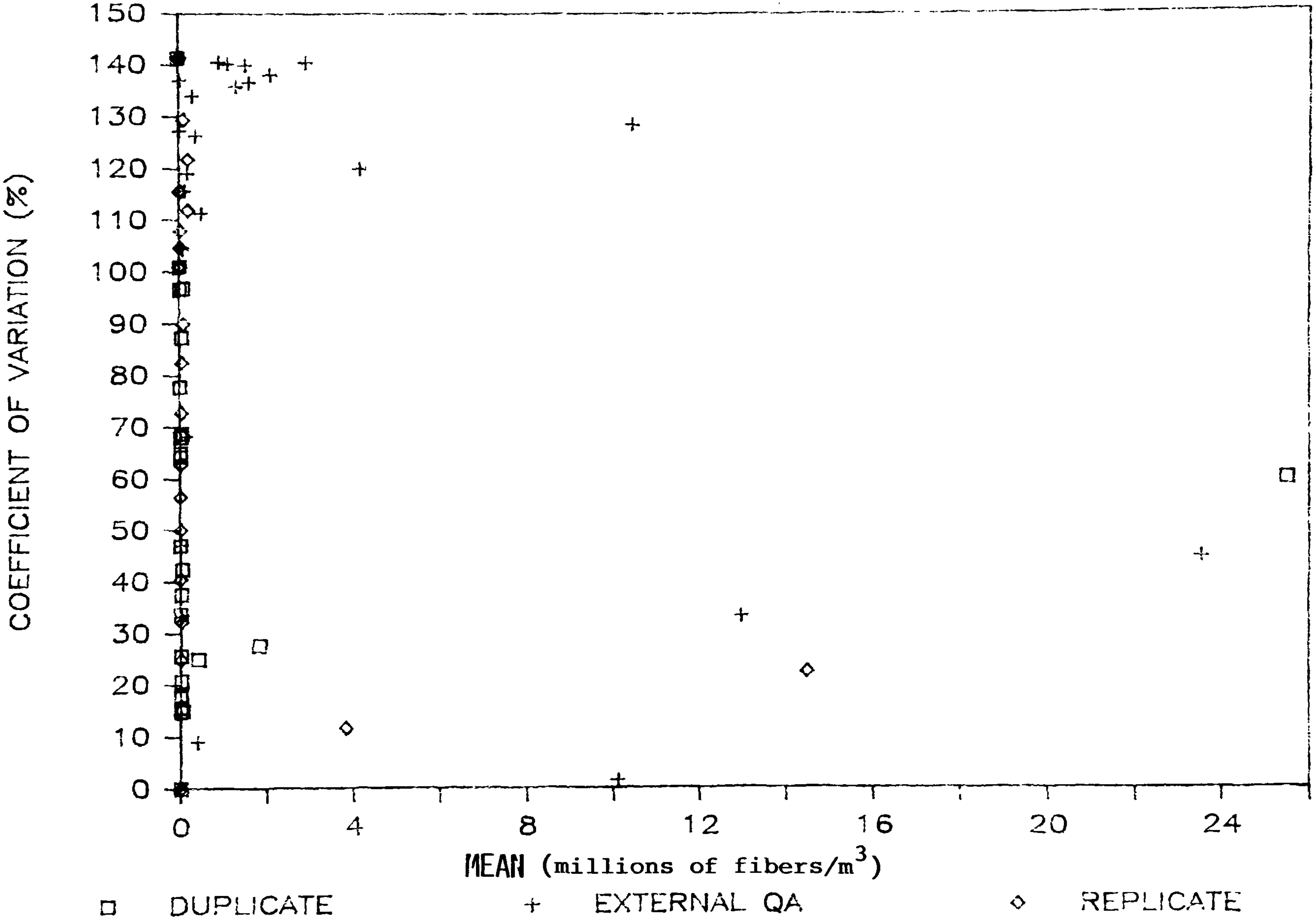

Figure 2. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean fiber concentration (millions of fiber/m3) measured by TEM. The total range of mean values are plotted.

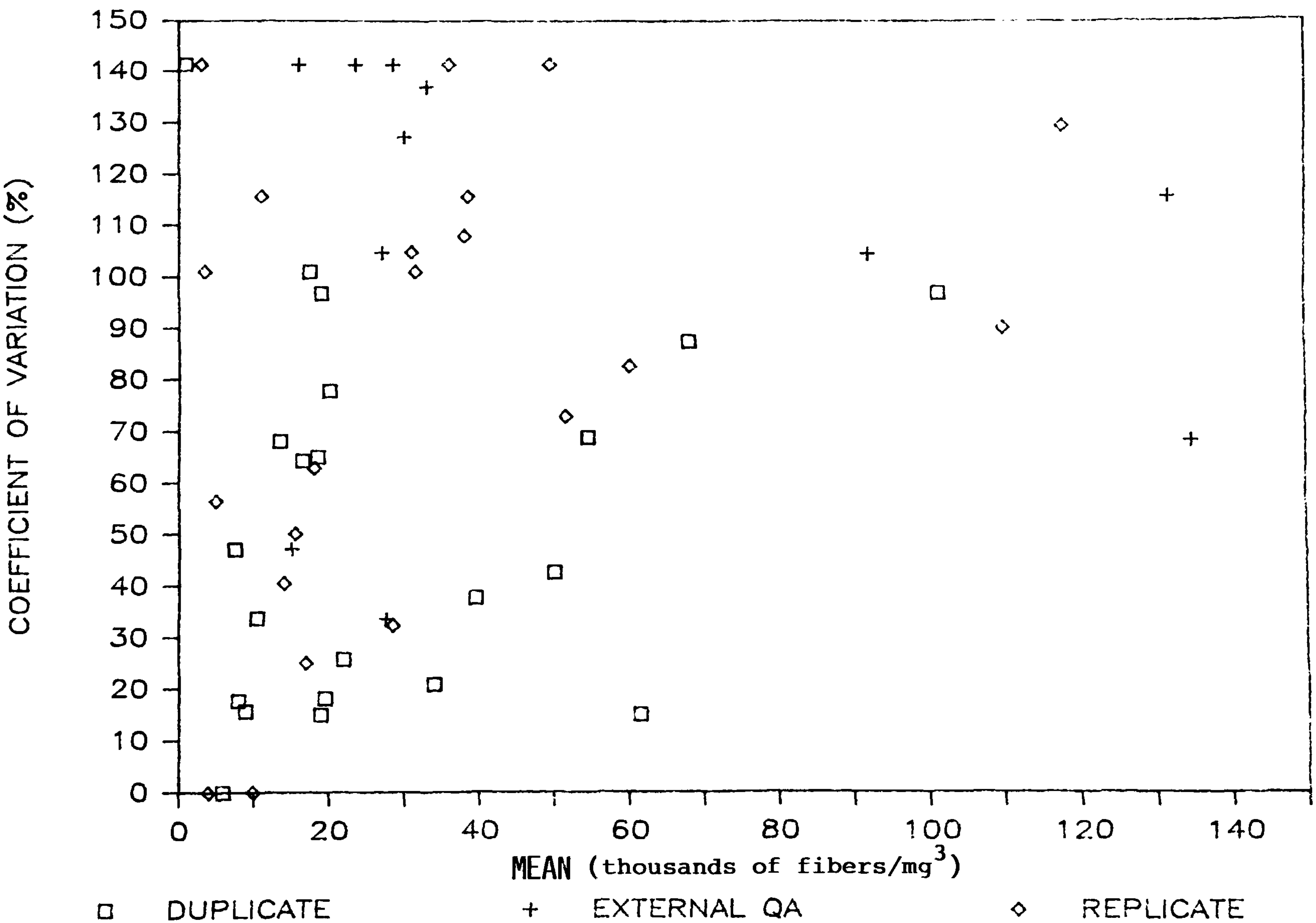

Figure 3. Coefficient of variation for duplicate and external QA analyses plotted against the mean fiber concentrations (thousands of fibers/m^3) measured by TEM. Only the lower mean values are plotted.

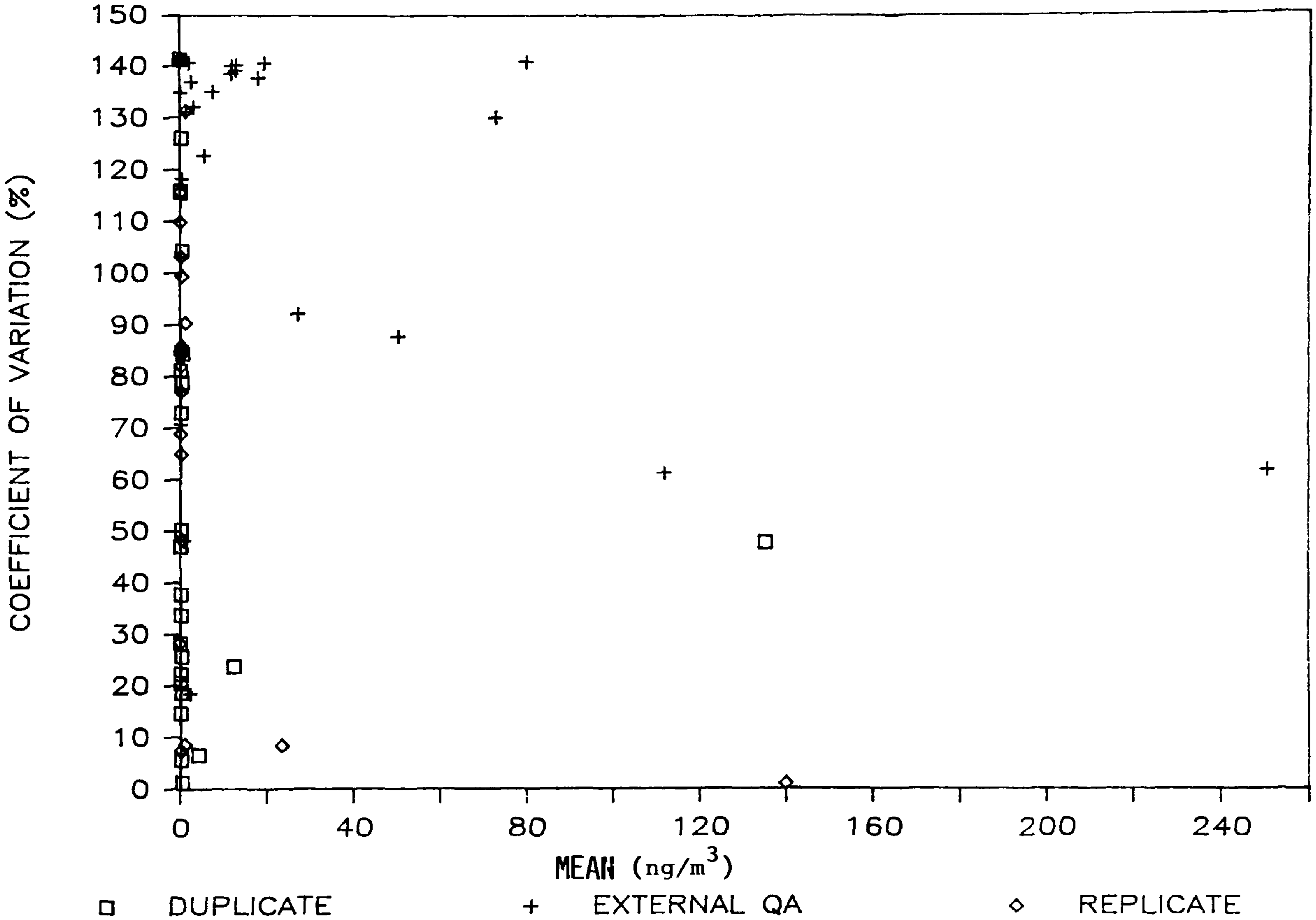

Figure 4. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean mass concentration (ng/m^3) measured by TEM. The total range of mean values are plotted.

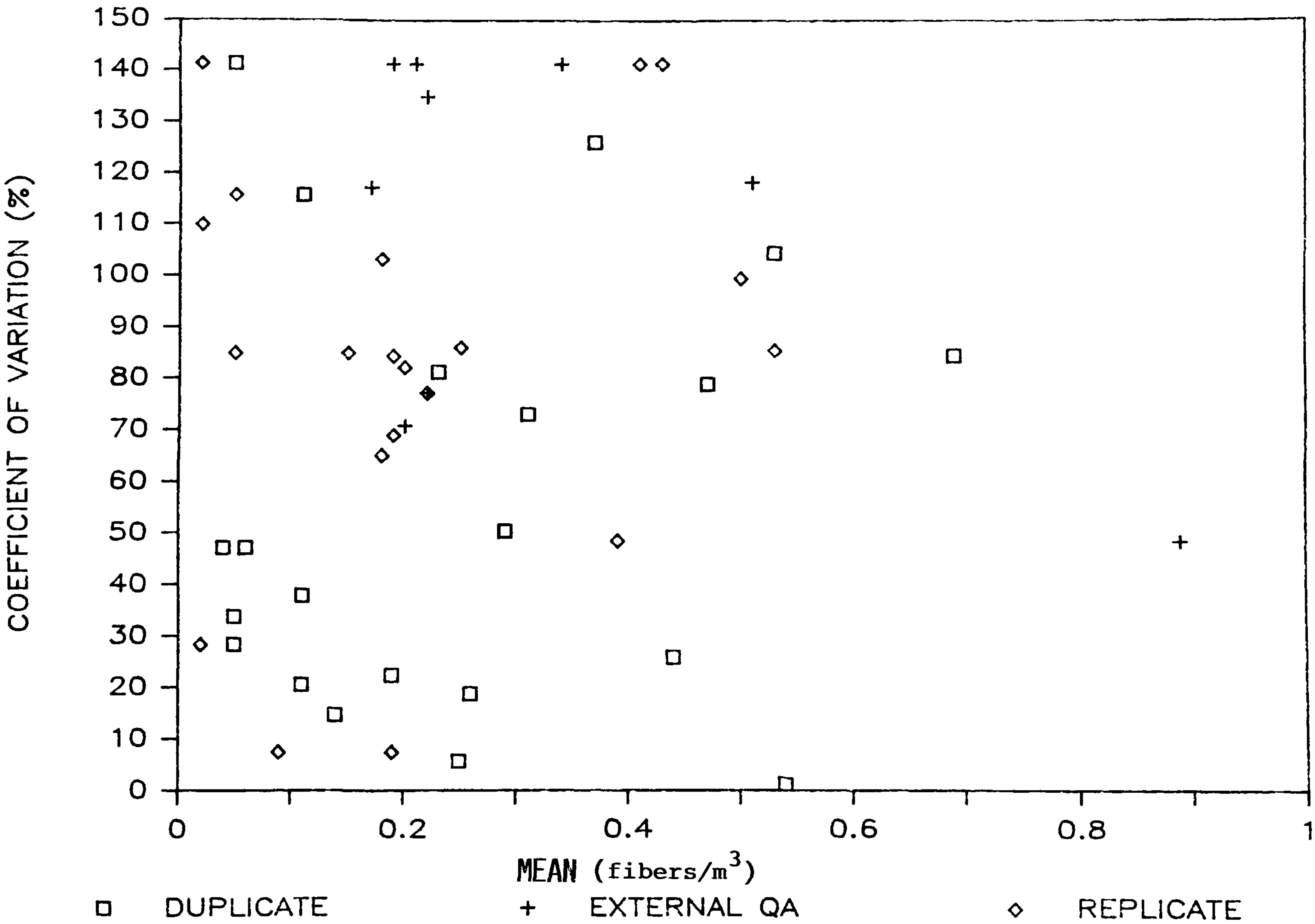

Figure 5. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean fiber concentration (fibers/m^3) measured by TEM. Only the lower mean values are shown.

As with the TEM fiber concentrations, the CV values for TEM mass concentrations were similar for duplicate, replicate, and external QA samples (Figures 4 and 5).

It appears that the external QA laboratory obtained results that tended to be higher than those obtained at BCL (Appendix C-4). Further analyses are in progress to try to determine the reason for this.

As a means of checking for filter contamination in the field, one Millipore field blank was collected at each site and at each sampling period, giving a total of 85 field blanks. In the field, the filter blanks were taken directly from the filter box, placed in a petri filter holder, and carried to the laboratory with the exposed samples. The analyst did not know which samples were field blanks; these samples were prepared and analyzed like all other samples. A total of 12 field blanks were randomly selected (one field blank from each of the three types of sites for each of the four sampling periods) and subjected to TEM analysis. The results in terms of fiber counts, fibers per filter, and ng per filter are presented in Appendix C-4. No fibers were detected on half the field blanks. The other six field blanks yielded a low average asbestos count of 0.52 ng/filter (standard deviation of 0.44).

To check for possible contamination during the preparation procedures, 5 laboratory blank Millipore filters were subjected to standard laboratory procedures during preparation and analysis of the other samples. The laboratory blank was either a blank filter in an ashing tube or an empty tube placed beside each sample tube. Each sample was ashed in a test tube (the test tubes were never reused), and each sample test tube had a blank test tube placed beside it in the low temperature ashing chamber. The results are given in Appendix C-4. Of these five filters, two showed no contamination. The remaining three yielded a low average asbestos count of 0.37 ng/filter (standard deviation of 0.31).

B. Phase Contrast Microscopy (PCM)

One hundred and twenty-three PCM analyses (including 26 replicate and 23 duplicate analyses) were performed on 5-day samples collected on Millipore filters. These same filters were also analyzed by TEM.

1. Methods

The protocol for PCM is given in Appendix B-6. This is the standard NIOSH method (Leidel et al. 1979). It considers only fibers that are longer than 5 μm and does not distinguish asbestos fibers from other types of fiber. A section of the membrane filter is cleaned and placed beneath a coverslip on a microscope slide. A phase microscope equipped with a Porton reticle is used to count fibers within 100 fields.

2. Discussion

Under the conditions of this study, the smallest fiber width that could be measured by PCM was 0.3 to 0.5 µm. Results, in terms of fibers/m^3, are given in Appendix C-2. The fiber concentration includes all fibers, asbestos and nonasbestos, as specified by the protocol. Although positive identification was not made, in the opinion of the microscopist, most of the fibers appeared to be nonasbestos.

3. Quality Assurance

The phase contrast microscopy was carried out at BCL on 5-day samples collected on Millipore filters. Of the 74 filters collected, 23 were randomly selected to be analyzed in duplicate and 26 to be analyzed in replicate. Twenty-nine randomly selected samples were split in halves and one-half of each of these samples was hand-carried to EMS Laboratories for external quality assurance analysis. Duplicate, replicate, and quality assurance analyses were carried out. Fiber counts and fiber concentrations (fibers/m^3) for duplicate, replicate, and QA analyses are presented, side-by-side with the corresponding standard analysis results, in Appendix C-5. Only fiber concentrations were statistically evaluated.

The plots of the CV's against the means for fiber concentrations showed them to be similar for duplicate, replicate, and external QA analyses as noted for TEM (Figure 6). (The CV

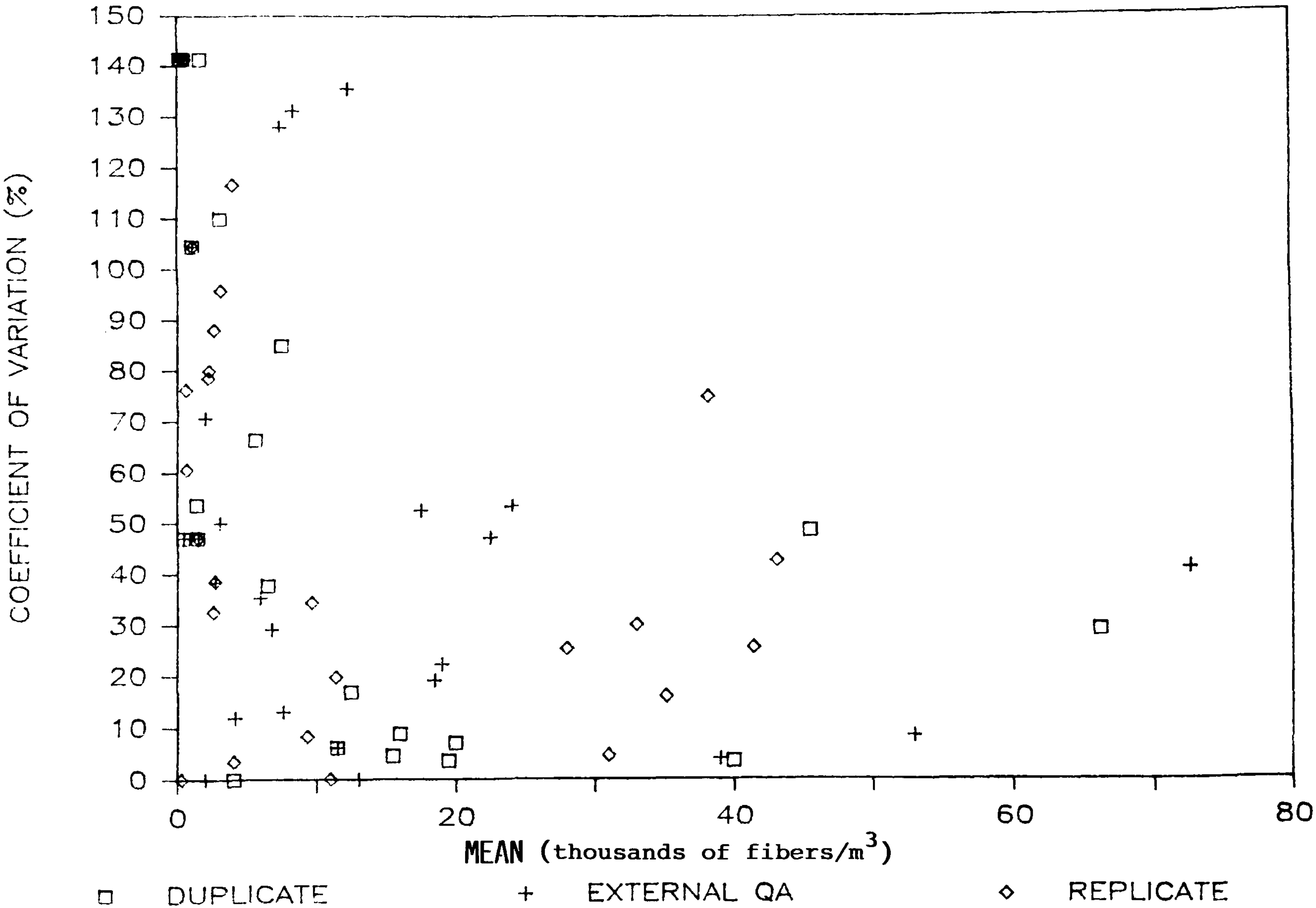

Figure 6. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean fiber concentration (thousands of fibers/m^3) measured by PCM.

values of ca. 141% were caused by one of the two values being zero as explained in the TEM QA section.) The standard deviations for PCM analyses were the greatest relative to TEM or SEM,and were nearly equal to or greater than the mean values recorded for the samples used for quality assurance.

C. Scanning Electron Microscopy (SEM)

Manual counting of asbestos fibers was performed using scanning electron microscopy (SEM) at 2,000X and 20,000X. A total of 108 analyses (including 23 replicates and 19 duplicates) were carried out.

1. Methods

All samples analyzed during this study were hand delivered to ETC. Since each sample was collected directly onto a Nuclepore filter, analysis of the collected sample was possible once the filter was carbon coated. In order to minimize sample loss through handling, carbon coating the filter was performed while it was still in the cassette. This involved carefully removing the top half of the plastic cassette and placing the sample(s) in a carbon evaporator. In this manner, the entire filter was coated with a thin layer of carbon. A portion of the carbon-coated filter was directly mounted on a polished carbon planchette SEM stub.

The samples were analyzed using an ETEC Autoscan scanning electron microscope (SEM) equipped with a Tracor Northern energy dispersive spectrometry X-ray analyzer (EDS). An electron beam accelerating potential of 20 kV was used with a specimen current of 0.5×10^{-9} A, and a working distance of 13 mm. During the SEM-EDS analysis, the samples were analyzed at magnifications of 2,000X and 20,000X. A two-second raster rate was used for all analyses.

Stated briefly, the SEM-EDS analysis was performed by placing the sample in the SEM and evacuating the sample chamber. Once vacuum is achieved, the electron beam can be focused on the sample's surface. The interaction of the electron beam with the sample produces various effects that can be monitored with suitable detectors. Secondary and/or backscattered electrons are used to create a viewing image, while the X-ray emission is monitored to determine the elemental chemistry of observed fibers and thus to identify asbestos.

The filter was scanned for the presence of fibers at 2,000X and 20,000X over an area representing at least one hundred (100) nonoverlapping fields. Each fiber observed was recorded on the data sheet. Fiber dimensions (length and width in micrometers) were measured from the SEM viewing screen. Fiber identity was determined using morphology and elemental composition via EDS for representative fibers. After representative fibers were characterized, additional fibers were classified on the basis of morphology. Fibers of questionable identity were also analyzed by EDS.

2. Discussion

A full account of the results of the SEM analyses is given in a separate report*. For this study, the number and dimensions of chrysotile fibers were used to obtain estimates of fiber concentration (fibers/m^3) and mass concentration (ng/m^3) following the same methods as those used for TEM (Appendix B-5). The estimates appear in Appendix D-1. Other types of asbestos fibers were occasionally observed, but only chrysotile fibers, which were the most common, were used in the calculations.

The minimum fiber width that can be detected under the conditions of the study is 0.1 - 0.3 µm. The minimum length is 1 µm. Particles that are counted as individual fibers by SEM would probably be considered bundles using TEM because of the differences in the detection limits of the two methods, with the

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*Nordstrom RL and Casuccio, GS. The identification of asbestos in ambient samples by scanning and transmission electron microscopy. Report to Research Triangle Institute, May 1984.

latter technique being able to identify individual fibers more easily. Since bundles are excluded from fiber and mass concentration estimates obtained by TEM, it is possible that there is very little overlap between the fiber sizes measured by SEM and those measured by TEM.

3. Quality Assurance

Sixty-six Nuclepore filter analyses were performed by ETC and RTI, of which 19 analyses were performed in duplicate and 23 in replicate, and 25 filters were selected for external quality assurance analysis by EMS Laboratories. Fiber counts at 2000X magnification, fiber concentrations (fibers/m^3), and mass concentrations (ng/m^3) for duplicate, replicate, and QA analyses are shown, side-by-side with the corresponding standard analysis results (Appendix C-6).

Asbestos fibers were counted during 6 of the 38 duplicate analyses (Appendix C-6). An evaluation of differences in variability in duplicate, replicate, and external QA samples is not possible because fibers were detected on a very low number of filters. The majority of the CV's calculated were ca. 141% due to reasons explained in the TEM QA section (Figures 7 and 8).

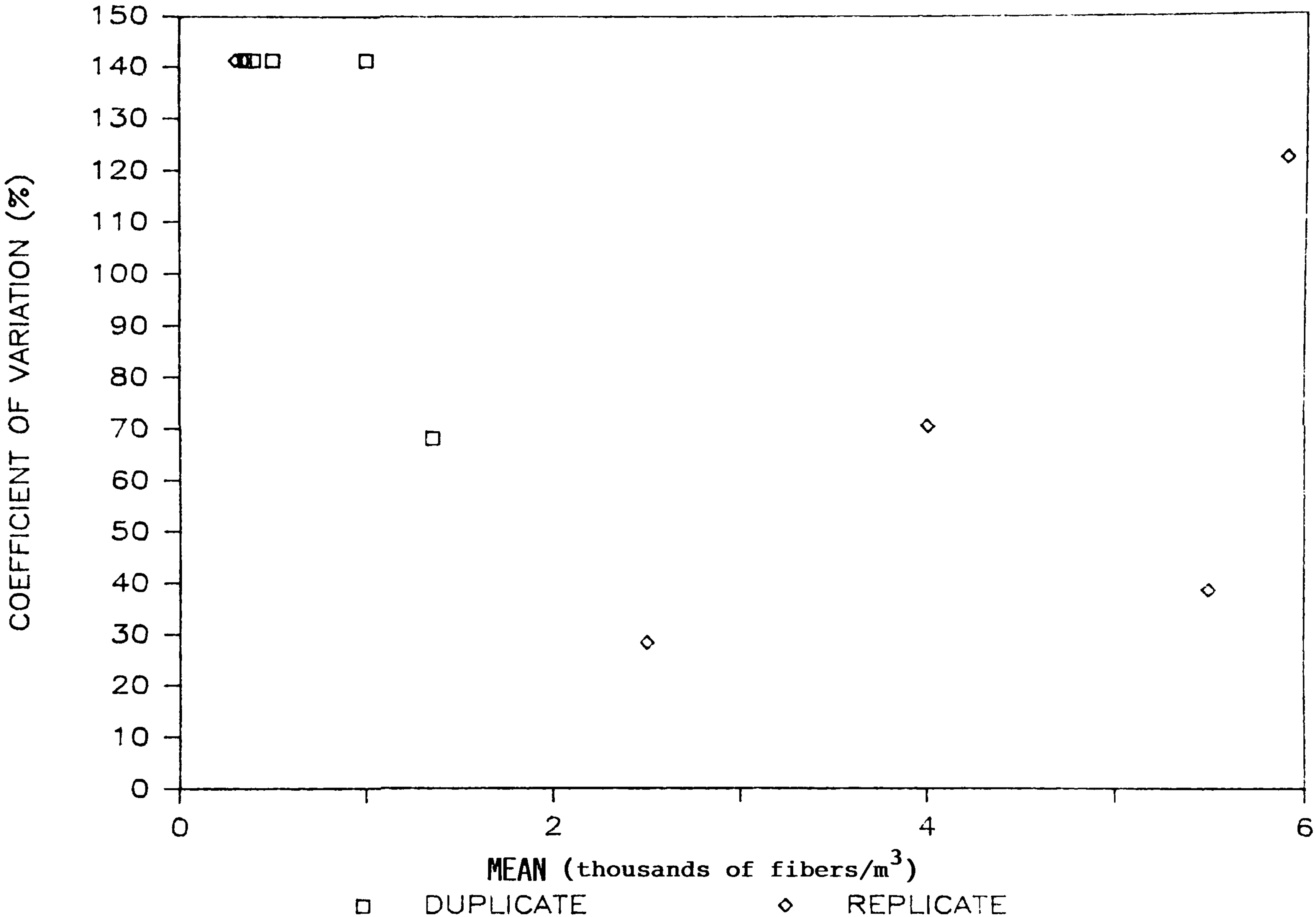


Figure 7. Coefficient of variation for duplicate and external QA analyses plotted against the mean fiber concentrations (thousands of fibers/m^3) measured by SEM.

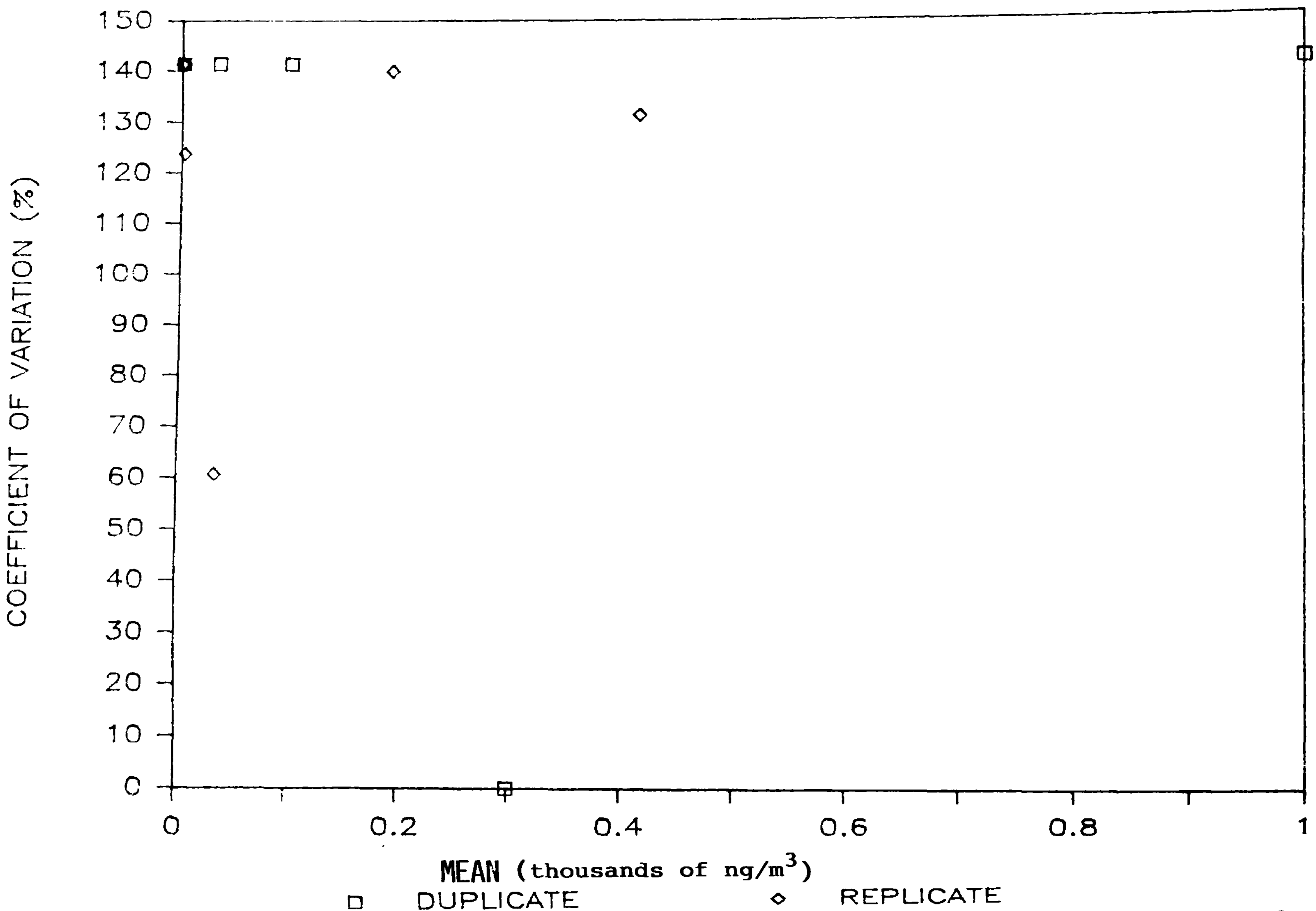


Figure 8. Coefficient of variation for duplicate and external QA analyses plotted against the mean mass concentration (thousands of ng/m3) measured by SEM.

For external quality assurance purposes, 25 filters were split in halves and one half sent to an external QA laboratory. Of these 25 filters, only 3 were found to have any fibers during analysis at the main laboratory, while 5 were found to have fiber deposits when analyzed by the QA laboratory, with a maximum of 3 agreements. Fiber concentrations ranged from 3 x 10^3 to 8.7 x 10^3 fibers/m^3 (3 measurements) for the main laboratory, and from 1.2 x 10^3 to 4.4 x 10^3 fibers/m^3 (5 measurements) for the QA laboratory (a slightly lower and smaller range). No further analyses of these data was attempted since most analyses yielded no fibers.

As a means of possible contamination check in the field or the laboratory, 11 field blanks and 2 laboratory blanks were analyzed following the same procedures as for the other filters. No fibers were detected on any of these 13 filter blanks.

II. BULK SAMPLES

Eight bulk samples, including two side-by-side samples, were collected at 14 air sampling sites and 1 additional site (Table 1) giving a total of 120 samples. Sixty of these 120 samples were selected to be (a) analyzed for asbestos and other materials by polarized light microscopy (PLM) procedures and (b) rated for releasability by stereomicroscopic techniques. The remaining samples have not been analyzed.

A. Polarized Light Microscopy (PLM)

Fifty-two of the 60 samples selected for analysis were analyzed by PLM techniques at MRI. Of these 52 samples, 7 were subjected to a blind duplicate analysis by a second analyst at MRI and 7 samples (one of a pair of side by side samples) were used for replicate analysis. Eight samples (one of a pair of side by side samples) were analyzed by an external quality assurance laboratory, Environmental Health Laboratory, Macon, Georgia. In summary, there were 67 analyses of the 60 samples.

1. Methods

The MRI analytical procedures for PLM analysis followed the interim test method published by the EPA (1982).

For the analyses, MRI used a stereo zoom microscope capable of 8X to 40X magnification equipped with an external illuminator for oblique illumination,and a polarizing microscope (100X magnification) equipped with an external illuminator and dispersion staining objective.

Each bulk sample was emptied onto clean weighing paper, and the entire sample was examined as a whole through the stereomicroscope for layering, homogeneity, and the presence of fibrous material. Identification of macro-size nonfibrous components was usually possible at this point.

Subsamples of the bulk sample were selected using the stereomicroscope. They were then mounted onto a clean microscope slide in the appropriate index of refraction liquids for examination through the polarizing microscope.

The PLM procedure consisted of observing the characteristics of the subsample components with transmitted polarized light, crossed polars, slightly uncrossed polars, crossed polars plus the first-order red compensator, and the central stop dispersion staining objective. The observations obtained using the various techniques were used to identify the composition of fibrous and some of the nonfibrous components on the basis of morphology, sign of elongation, and refractive index/dispersion staining colors.

Volume percentages of the various materials were estimated in relationship to the whole sample.

2. <u>Discussion</u>

The results are given in Appendix C-3. Thirty-one PLM analyses, or 42%,showed 25% by volume of chrysotile. Fifty-two PLM analyses, or 78%, showed 25% or less by volume of chrysotile. The highest volume of chrysotile was 85% and the lowest 3%. Non-asbestos material predominance was shared by perlite and vermiculite.

3. Quality Assurance

A total of 52 bulk samples were analyzed by MRI; of these, 7 were analyzed in duplicate and 7 of these 52 samples were replicates (one sample from a pair of side by side samples). In addition, from each of the 8 side-by-side samples, one member was selected to be analyzed by EMS Laboratories for external quality assurance. The results of percent chrysotile content and releasability rating for duplicate, replicate, and external quality assurance, side-by-side with the corresponding standard analysis results, are presented in Appendix C-7.

The CV's calculated for the percent chrysotile was quite variable, ranging from ca. 0 to 115% (Figure 9). The CV's for the external QA analyses were the highest, showing that inter-laboratory variability was higher than either duplicate or replicate analyses.

B. Releasability Rating

The 60 samples (67 analyses) (7 duplicate analyses, 7 replicate samples, and 8 external QA samples) were examined by stereomicroscopic technique and rated for the apparent availability of releasable fibers from the bulk material. They were rated on an arbitrary scale of 0 through 9. The rating is a subjective determination.

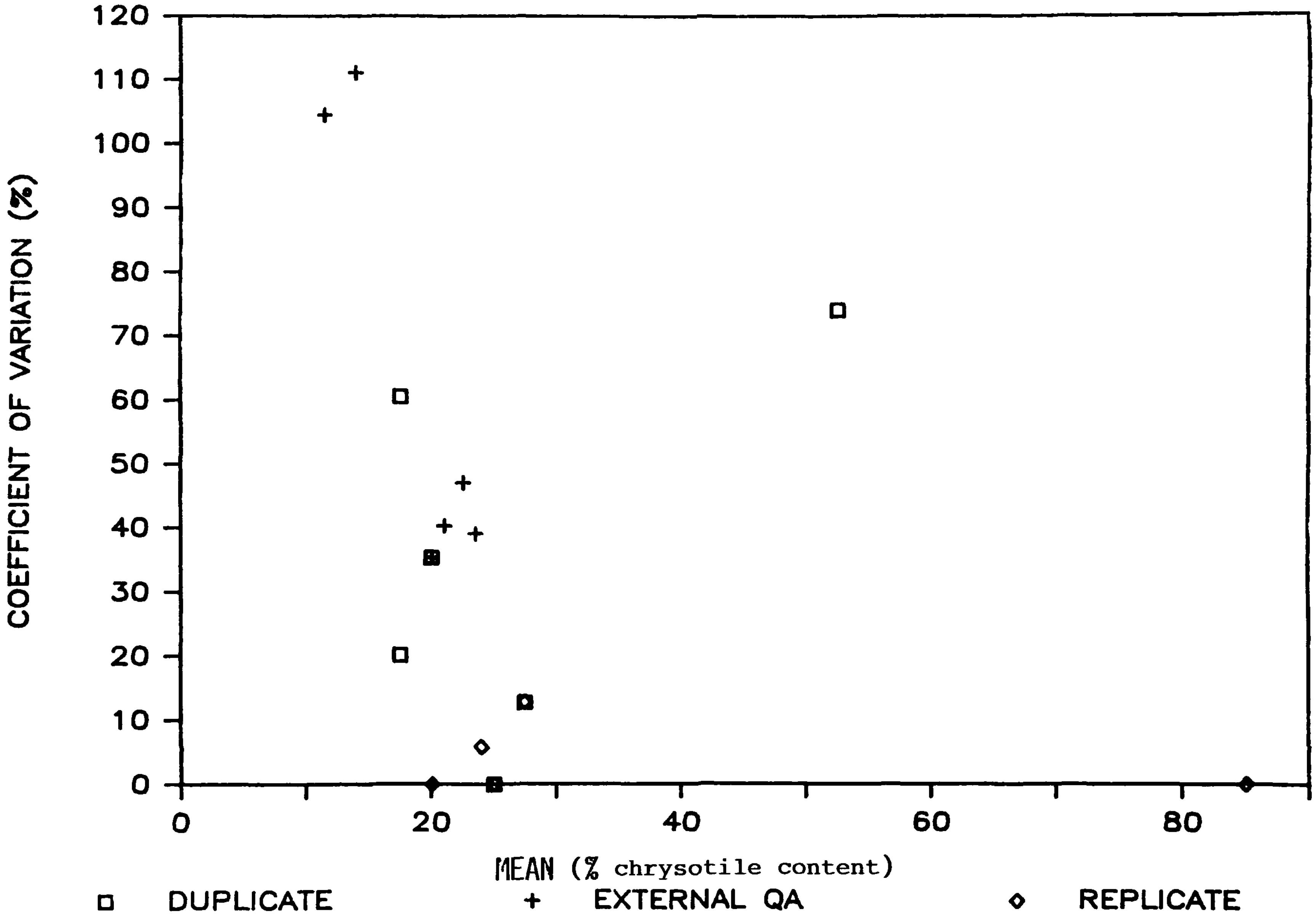


Figure 9. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean percent chrysotile content in bulk samples measured by PLM.

1. <u>Methods</u>

Determining the releasability rating involves consideration of the number of apparently free asbestos fibers as well as the friability of the matrix. Samples with large numbers of free asbestos fibers and those with brittle matrices easily broken or abraded are given a high numerical rating. Asbestos-containing samples with resilient or tough matrices, such as resin-bonded glass wool or resin-bonded vermiculite, are given a low numerical rating.

The method for determination of releasability (Atkinson et al. 1983) is the following:

(1) Determine the identity and concentration of the sample components by the usual microscopic means;

(2) Examine the sample under a stereomicroscope at approximately 10X magnification. Note the size and freedom of the fibers;

(3) Probe the sample with needles and note the brittleness, toughness, or resilience of the matrix; and,

(4) Rate the releasability on a scale of 0 to 9. Assign a low number to samples with low releasability, a high number to samples with high releasability.

2. Discussion

The results are given in Appendix C-3. Eighty-two percent of the samples had a rating of 4, 5, or 6. Thirty-nine percent of the samples had a rating of 5, 28% had a rating of 6, and 15% had a rating of 4. The extremes were one sample with an 8 rating and nine samples with a 3 rating. There were three samples with a 7 rating.

3. Quality Assurance

The CV's calculated for the releasability ratings were generally less than those calculated for the percent chrysotile (Figure 10). The CV's were all less than 50%.

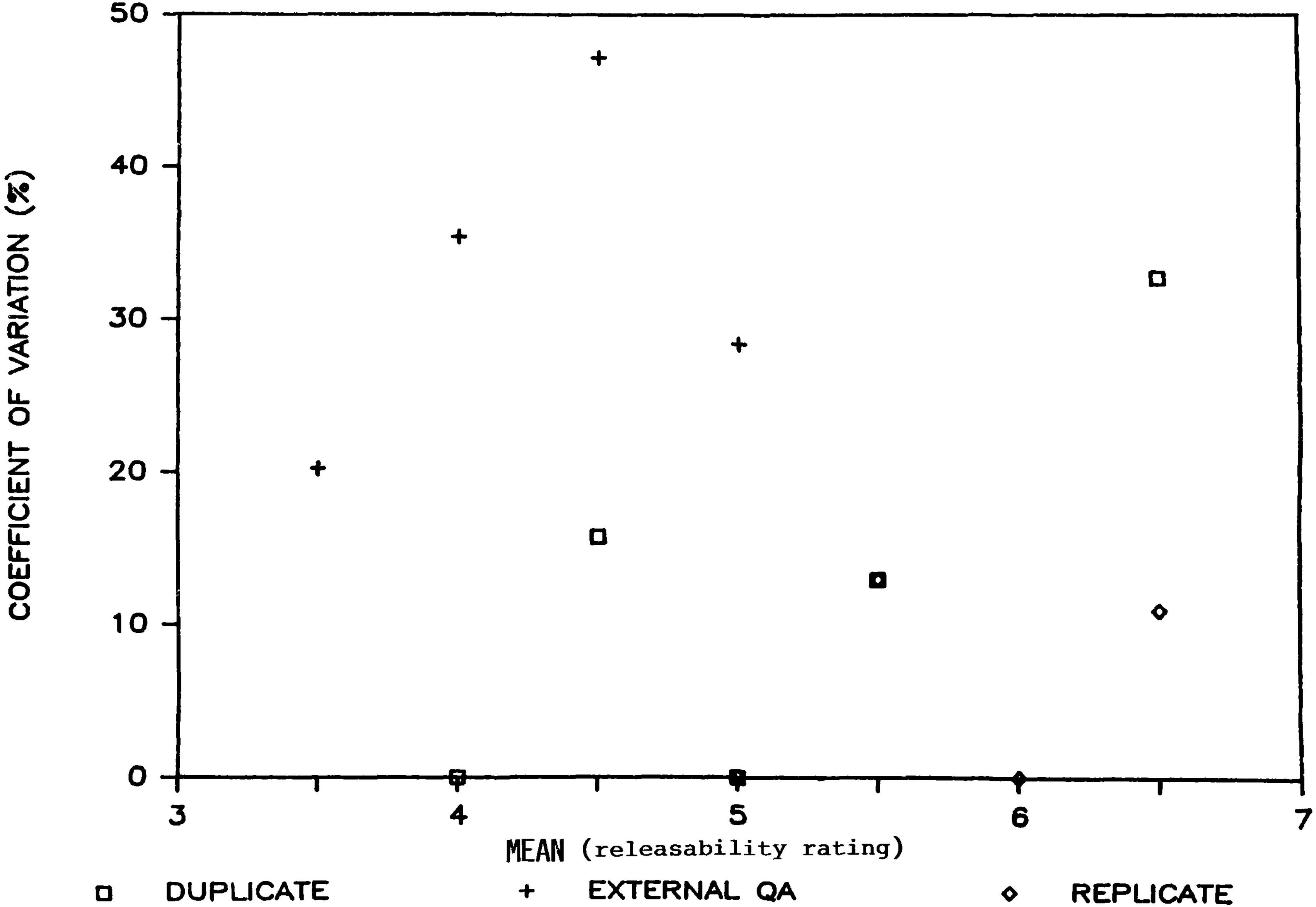


Figure 10. Coefficient of variation for duplicate, replicate, and external QA analyses plotted against the mean releasability rating for bulk samples measured by PLM.

SECTION 7

STATISTICAL ANALYSIS

The statistical analysis of the data was directed at the two main objectives of the study:

(1) To compare airborne asbestos levels before, during, and after removal of the asbestos containing material; and,

(2) To compare TEM, SEM and PCM as methods of assessing airborne asbestos levels.

A secondary objective was to investigate the relationship between airborne asbestos levels and properties of the bulk samples.

Airborne asbestos levels are expressed as fiber concentration (fibers/m^3) and as mass concentration (ng/m^3). The mass is calculated directly from the dimensions of each fiber measured under the microscope. Only chrysotile asbestos is considered since other types of asbestos fibers were rarely found. The analysis methods are discussed in more detail in the next section. Subsequent sections discuss each objective in turn and present the results of the statistical analyses. Data listings are given in Appendix D.

I. ANALYSIS METHODS

Summary statistics are presented in graphs and tables. The distribution of airborne asbestos levels tends to be skewed to the right with high levels occurring more often than would be expected if the distribution were symmetrical about its mean. When this is the case, the arithmetic mean can be unduly inflated. To take this into account, the natural logarithm of the levels was used in the statistical tests. The transformations used were $\log_e(X+1)$ for fiber concentration (fibers/m^3) and $\log_e(1,000X+1)$ for mass concentration (ng/m^3). The inclusion of the 1 means that zero values on the original scale are also zero on the transformed scale. Analysis of the transformed data is equivalent to working with the geometric mean. The geometric mean is often regarded as a more appropriate measure of central tendency or location for skewed data, and is presented in the summary tables. The geometric mean is the same as the median for the lognormal distribution.

Analysis of variance and the nonparametric Kruskal-Wallis test (which does not assume a particular distribution) were used to test hypotheses about the effect of school, the type of site and the sampling period on airborne asbestos levels. The p-value associated with each test indicates the probability of obtaining, due to sampling error alone, an effect as large or larger than the effect that was observed. Thus, a large p-value indicates that the observed effects are likely to be due to chance, whereas a small p-value indicates that the observed effects are most likely due to real differences. The conventional value of $p < 0.05$ is taken as the level of statistical significance.

Correlation coefficients are used to measure the degree of association between results obtained to different analytical methods. The maximum value is 1. If there is no relationship between the two sets of results, the correlation coefficient is 0. A large p-value associated with a correlation coefficient indicates that the correlation is not significantly different from zero.

In this study the airborne asbestos levels are generally low. Therefore it is not uncommon, particularly with SEM, for some estimates to be based on a few (< 10) fibers. The large uncertainty associated with such an estimate means that little confidence can be placed in the actual numberical value of a single observation. This should be kept in mind when interpreting the results. It was felt that the estimates still provided useful information about trends in airborne asbestos levels, particularly when an estimate is based on several measurements, and therefore they were included in the statistical analyses. Although the problem is severe for SEM, it is much less serious for TEM and PCM. Fiber counts for the latter two methods are often greater than 10 (Appendix D-1).

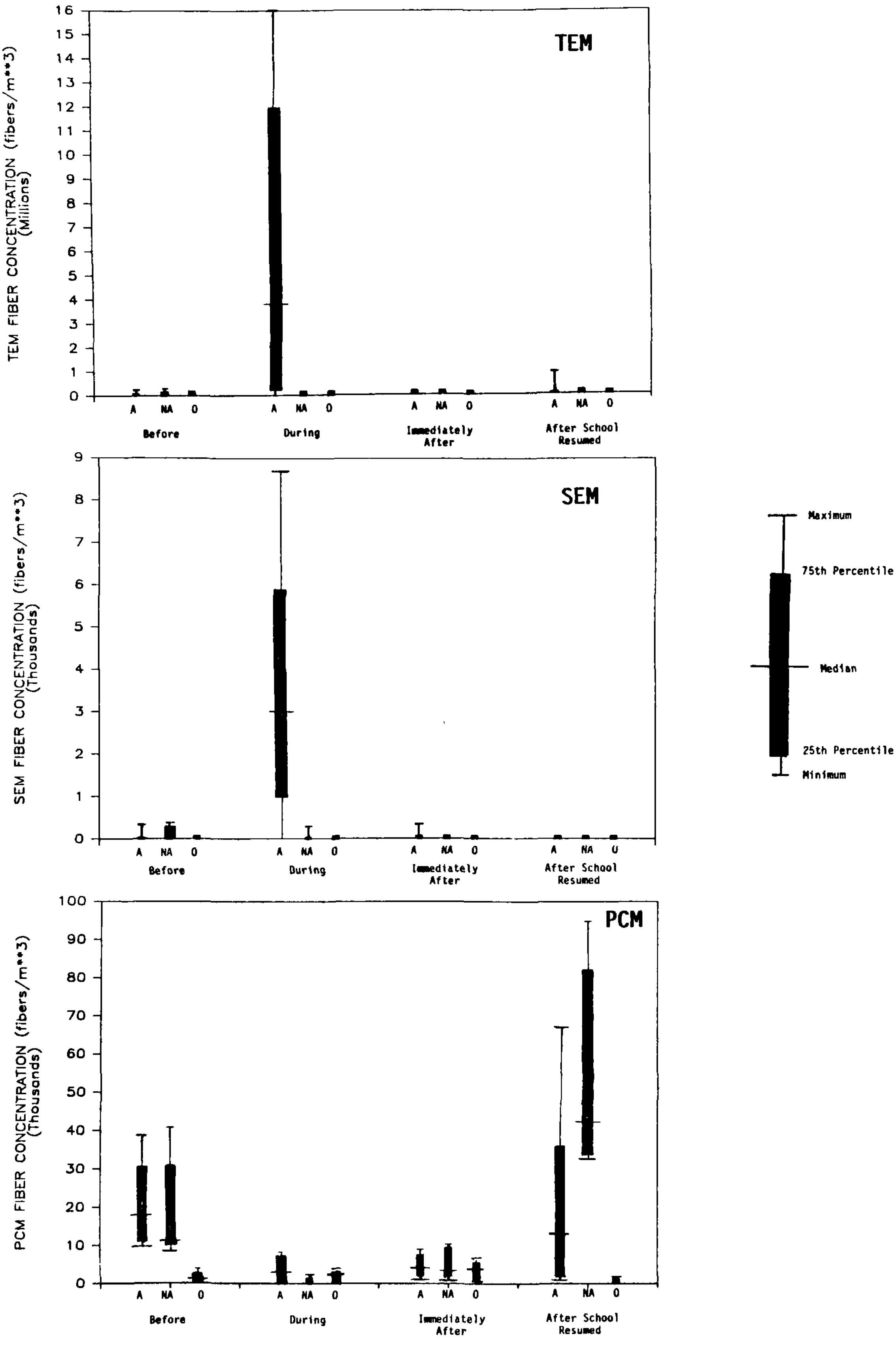
II. AIRBORNE ASBESTOS LEVELS BEFORE, DURING, AND AFTER ABATEMENT

The first objective of this study was to compare airborne asbestos concentrations at selected sites before, during, and after complete removal of the asbestos material. The data used for this comparison came from 5-day air samples collected simultaneously on Millipore and Nuclepore filters. Millipore filters were analyzed by both PCM and TEM. Nuclepore filters were analyzed by SEM. Where replicate or duplicate analyses were done on the same filter, the arithmetic mean of the two values was used in the statistical analysis. Results from the external QA analyses are not included.

Figure 11 summarizes the results for each sampling period and each analysis method. The results are discussed in more detail below.

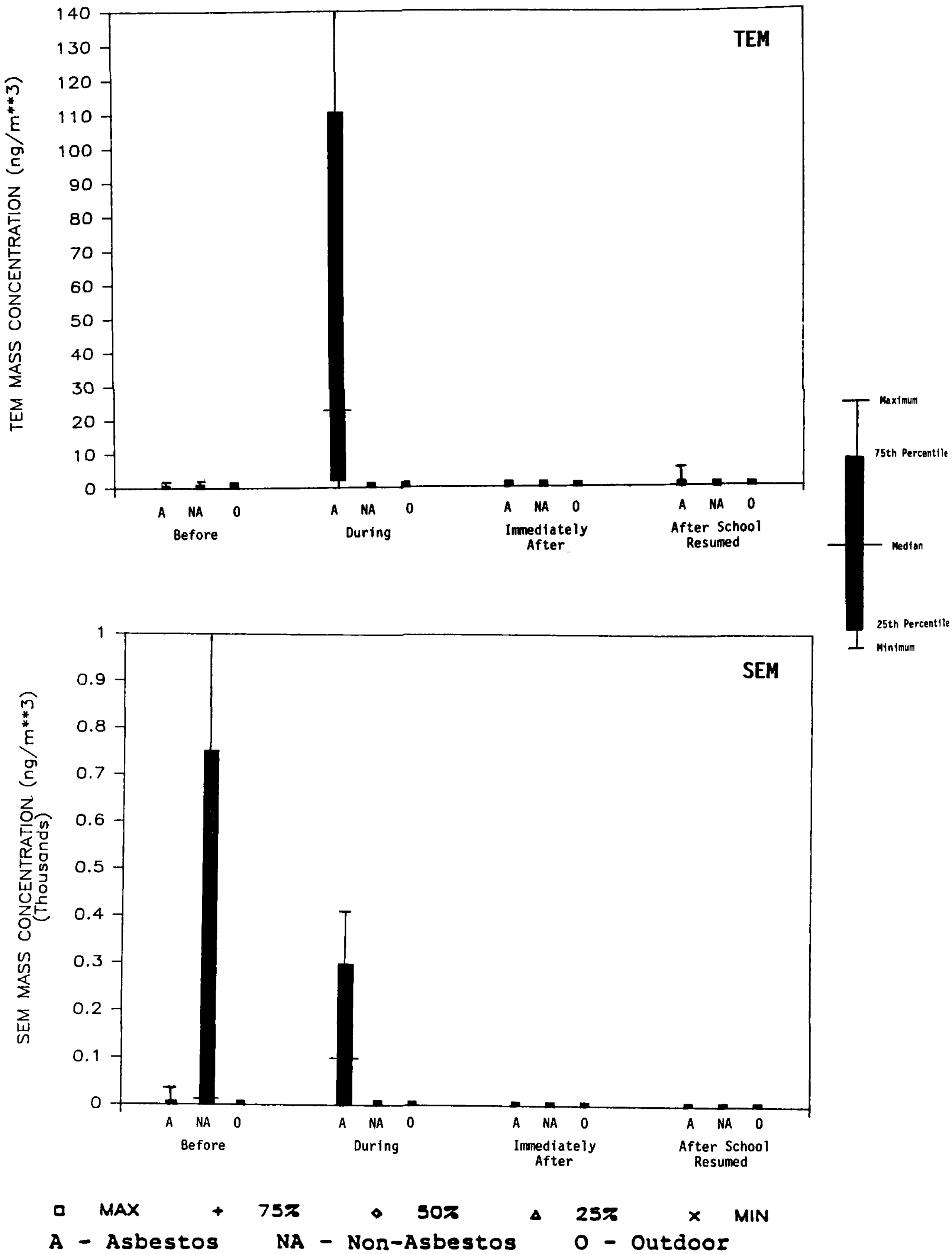
A. TEM Results

Fiber concentration (fibers/m^3) and mass concentration (ng/m^3), as measured by TEM, were low both before and after asbestos removal (<$1x10^6$ fibers/m^3 and <6 ng/m^3, respectively). Relative to the levels before and after removal, airborne asbestos levels were higher during removal (up to $16x10^6$ fibers/m^3 and 140 ng/m^3, respectively), though these levels were still low (Appendix E). The trends are apparent when values are averaged within site types (asbestos, nonasbestos, and outdoor), within a school, and over schools. Fiber concentrations at all



(a) Fiber concentration

Figure 11. Summary of air sampling results. The distribution of values for each sampling period and site type is indicated by the maximum, minimum and 75th, 50th (median), and 25th percentiles.



(b) Mass concentration

Figure 11. (Continued)

four schools were highest at asbestos-containing sites during removal (Table 3). These sites were located outside the containment area but close to the barriers separating the work area from the rest of the school. A negative air pressure system was not used during the removal operation. The nonasbestos and outdoor sites did not have elevated levels during removal. Mass concentrations follow the same pattern. Table 4 provides a summary of the results averaged across all schools.

Two-way analyses of variance with school and sampling period as the two factors were carried out on the log-transformed data. At asbestos-containing sites, both fiber density and mass concentration differ significantly ($p < 0.01$ and $p < 0.0001$, respectively) between sampling periods. When the "during" period is eliminated from the analysis, significant differences are no longer present. Thus, the differences can be explained by elevated levels during abatement and there is no significant difference between levels before and after removal. There is no statistically significant difference between periods at either nonasbestos-containing or outdoor sites ($p > 0.05$). Levels at these two categories of sites remained low throughout the study. There are no statistically significant interactions between school and sampling period. This indicates that similar trends were seen at all schools.

Table 3. Average Chrysotile Fiber and Mass Concentrations (in Fibers/m^3 and ng/m^3, Respectively) Measured by TEM at Each School and Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

		PERIOD							
		BEFORE REMOVAL		DURING REMOVAL		SHORTLY AFTER REMOVAL		AFTER SCHOOL RESUMED	
		TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3
		GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
SCHOOL	TYPE								
1	ASBESTOS	7.7	0.1	1800.0	12.0	10.0	0.1	40.2	0.2
	NON-ASBESTOS	320.0	1.6	3.0	0.0	60.0	0.5	55.0	0.2
	OUTDOOR	34.0	0.2	3.0	0.0	.	.	4.0	0.0
2	ASBESTOS	29.8	0.3	996.7	8.1	1.5	0.1	7.0	0.0
	NON-ASBESTOS	23.0	0.1	29.2	0.3	0.1	0.0	11.8	0.1
	OUTDOOR	3.0	0.0	0.0	0.0	.	.	17.0	0.1
3	ASBESTOS	46.4	0.3	1792.6	15.4	23.8	0.3	39.7	0.3
	NON-ASBESTOS	0.2	0.0	9.8	0.2	3.0	0.0	14.0	0.2
	OUTDOOR	3.5	0.0	18.0	0.3	21.0	0.1	3.0	0.0
4	ASBESTOS	61.6	0.4	14000.0	140.0	7.5	0.0	61.0	0.3
	OUTDOOR	70.0	0.6	49.0	0.4	19.0	0.1	19.0	0.1

Table 4. Average Chrysotile Fiber and Mass Concentrations (in Thousands of Fibers/m^3 and ng/m^3, Respectively) Measured by TEM at Each Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

	PERIOD							
	BEFORE REMOVAL		DURING REMOVAL		SHORTLY AFTER REMOVAL		AFTER SCHOOL RESUMED	
	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3	TEM-CHRYS-FIBERS/M**3 (THOUSANDS)	TEM-CHRYS-NG/M**3
	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
TYPE								
ASBESTOS	31.2	0.2	1736.0	14.4	5.6	0.1	23.9	0.2
NON-ASBESTOS	6.1	0.1	12.0	0.1	1.6	0.0	18.1	0.1
OUTDOOR	12.6	0.1	1.3	0.0	20.0	0.1	7.9	0.0

The results of the nonparametric Kruskal-Wallis test agree with those of the analysis of variance indicating that the results are not sensitive to the assumption of a lognormal distribution. Levels are significantly different between sampling periods at asbestos-containing sites ($p < 0.01$ and $p < 0.0001$) for fiber concentration and mass concentration, respectively), but are not significantly different ($p < 0.05$) at nonasbestos-containing and outdoor sites.

B. SEM Results

Asbestos fibers were detected by SEM on only 14 (21%) of the filters. Therefore, the estimated fiber concentration and mass concentrations were below detection limit in most cases and were set to zero. Eleven (79%) of the nonzero estimates were obtained during asbestos removal. Thus, despite the small number of fibers counted, the SEM results show a similar pattern to the TEM results (Figure 11). Fiber concentrations range from 0 to $9x10^3$ fibers/m^3 and mass concentrations range from 0 to 1,000 ng/m^3 (Appendix E). The large value of 1,000 ng/m^3 is based on only 1 fiber and is discussed further in section 7-C where the three analytical methods are compared. The data are summarized across sites and across schools and sites in Tables 5 and 6.

Table 5. Average Chrysotile Fiber and Mass Concentrations (in Thousands of Fibers/m^3 and ng/m^3, Respectively) Measured by SEM at Each School and Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

		PERIOD							
		BEFORE REMOVAL		DURING REMOVAL		SHORTLY AFTER REMOVAL		AFTER SCHOOL RESUMED	
		SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3
		GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
SCHOOL	TYPE								
1	ASBESTOS	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	NON-ASBESTOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OUTDOOR	0.0	0.0	.	.	0.0	0.0	0.0	0.0
2	ASBESTOS	0.0	0.0	1.6	16.3	0.0	0.0	0.0	0.0
	NON-ASBESTOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OUTDOOR	0.0	0.0	.	.	0.0	0.0	0.0	0.0
3	ASBESTOS	0.0	0.0	3.3	314.6	0.0	0.0	0.0	0.0
	NON-ASBESTOS	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	OUTDOOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	ASBESTOS	.	.	6.6	216.4	.	.	.	.
	OUTDOOR	.	.	0.0	0.0	.	.	.	.

Table 6. Average Chrysotile Fiber and Mass Concentrations (in Thousands of Fibers/m^3 and ng/m^3, Respectively) Measured by SEM at Each Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

	PERIOD							
	BEFORE REMOVAL		DURING REMOVAL		SHORTLY AFTER REMOVAL		AFTER SCHOOL RESUMED	
	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3	SEM-CHRYS-FIBERS/M**3 (THOUSANDS)	SEM-CHRYS-NG/M**3
	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
TYPE								
ASBESTOS	0.0	0.0	1.4	20.2	0.0	0.0	0.0	0.0
NON-ASBESTOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OUTDOOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Both the two-way analysis of variance and the Kruskal-Wallis test show a significant difference between sampling periods at asbestos-containing sites ($p < 0.0001$ and $p < 0.0001$, respectively). At nonasbestos-containing and outdoor sites almost all the levels are zero and formal statistical analyses were not done.

C. PCM Results

Fiber densities reported by PCM include both asbestos and non-asbestos fibers. Fiber dimensions are not measured. Therefore, mass concentrations cannot be calculated. Fiber concentrations range from 0 to 9.4×10^3 fibers/m^3 (Appendix E). There is no evidence of elevated fiber levels during abatement; in contrast to the TEM and SEM results. In fact, fiber concentrations appear to be highest before removal and after school resumed (Figure 11 and Tables 7 and 8). This may reflect the increase in human activity during these periods. Concentrations of non-asbestos fibers such as cellulose, hair etc. are expected to be higher when students are present and there is substantial student activity in the building. These non-asbestos fibers are included in the PCM measurements. There is a statistically significant difference between periods at asbestos-containing sites when the log transformed data are analyzed by either a two-way analysis of variance ($p < 0.05$) or the Kruskal-Wallis test ($p < 0.01$). At the non-asbestos sites the difference between periods is not as apparent with the two-way analysis of variance ($p = 0.08$) but is detected by the Kruskal-Wallis test ($p < 0.01$). No significant differences among periods were detected at the outdoor sites ($p > 0.05$).

Table 7. Average Fiber Concentration (in Thousands of Fibers/m^3) Measured by PCM at Each School and Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

		PERIOD			
		BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
		PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)
		GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
SCHOOL	TYPE				
1	ASBESTOS	14.8	7.5	6.5	0.5
	NON-ASBESTOS	11.0	0.0	9.6	33.0
	OUTDOOR	0.7	0.7	.	0.5
2	ASBESTOS	15.9	2.4	4.2	13.2
	NON-ASBESTOS	10.1	0.0	1.5	65.8
	OUTDOOR	3.1	2.3	.	0.0
3	ASBESTOS	26.0	3.1	3.8	11.4
	NON-ASBESTOS	29.7	0.3	3.3	38.0
	OUTDOOR	0.3	2.0	5.6	0.5
4	ASBESTOS	22.9	1.4	3.8	4.6
	OUTDOOR	2.0	0.2	2.0	0.0

Table 8. Average Fiber Concentration (in Thousands of Fibers/m^3) Measured by PCM at Each Type of Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

	PERIOD			
	BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
	PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)	PCM FIBERS/M**3 (THOUSANDS)
	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN	GEOMETRIC MEAN
TYPE				
ASBESTOS	19.7	2.8	4.2	6.2
NON-ASBESTOS	15.8	0.0	3.5	48.3
OUTDOOR	1.1	0.8	3.3	0.0

III. COMPARISON OF SAMPLING AND ANALYTICAL PROTOCOLS

The second main objective of this study was to compare different methods of measuring airborne asbestos levels.

Multiple samples were collected simultaneously at each site to provide comparisons between different sampling times (3-day and 5-day) and three analytical methods: TEM, SEM and PCM.

A. Sampling Duration

Air samples of approximately 22.5 hours ("3-day") and 37.5 hours ("5-day") duration were collected on Millipore filters. The results described int he preceding section are based on the 5-day samples. Thirty-three 3-day samples from the first (before abatement) and third (immediately after abatement) sampling period were analyzed by TEM. As it became apparent that the airborne asbestos levels were very low, and would not allow a useful comparison between the two sampling times, analysis of the 3-day samples was discontinued.

B. Analytical Method

The three analytical methods (TEM, SEM and PCM) detect fibers of different sizes (Figure 12). In addition, PCM does not distinguish asbestos fibers from other types of fibers. Therefore, the numerical estimates of fiber and mass concentration will depend on the method used. Even though the actual numerical values will differ, the estimates should be highly correlated if the methods are to be regarded as

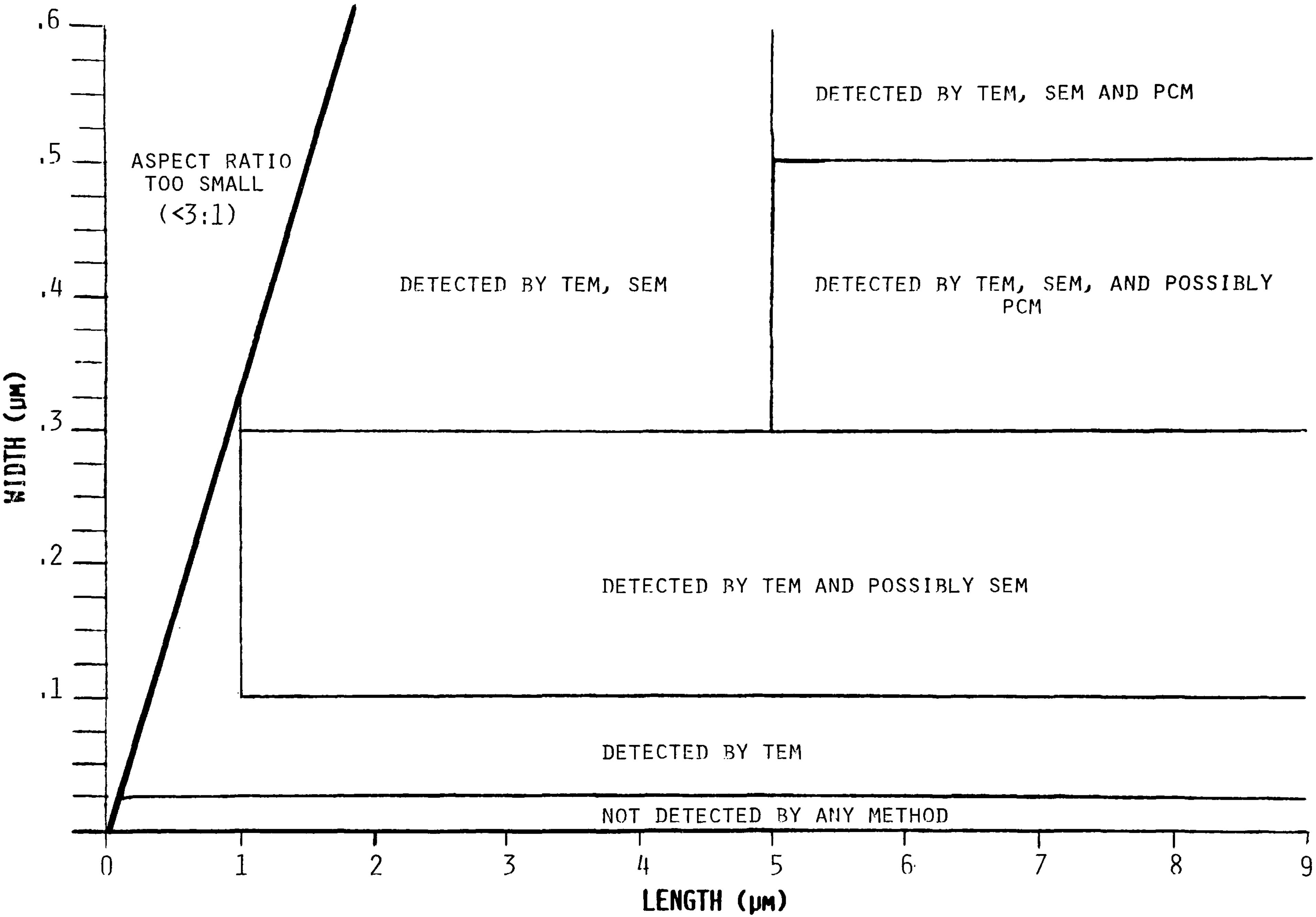


Figure 12. Range of fiber sizes that can be detected by three analysis methods under the conditions of this study.

alternatives for measuring airborne asbestos levels. A low correlation implies, for example, that higher levels measured by one method do not correspond to higher levels measured by another. This could occur if the distribution of fiber sizes changes with fiber concentration, or in the case of PCM, if there are changes in the concentrations of other non-asbestos fibers.

Each 5-day Millipore sample analyzed by TEM was also analyzed by PCM. Therefore a direct comparison of the two methods, based on analysis of identical samples, is possible. At most sites an air sample was also collected on a Nuclepore filter. The Nuclepore samples were collected at the same time as the Millipore samples and therefore should represent the same airborne levels although they may differ by chance because they are different samples. The Nuclepore filters were analyzed by SEM.

There are 60 site/period combinations where air samples were analyzed by both TEM and SEM. The results for fiber concentration are plotted in Figure 13 and those for mass concentration in Figure 14. The correlation coefficient for fiber concentration (of the log transformed data) is 0.56 with a p-value of 0.0001 indicating that the correlation is significantly different from zero. For mass concentration the correlation coefficient is 0.62 with a p-value of 0.0001. Thus, for both variables there is

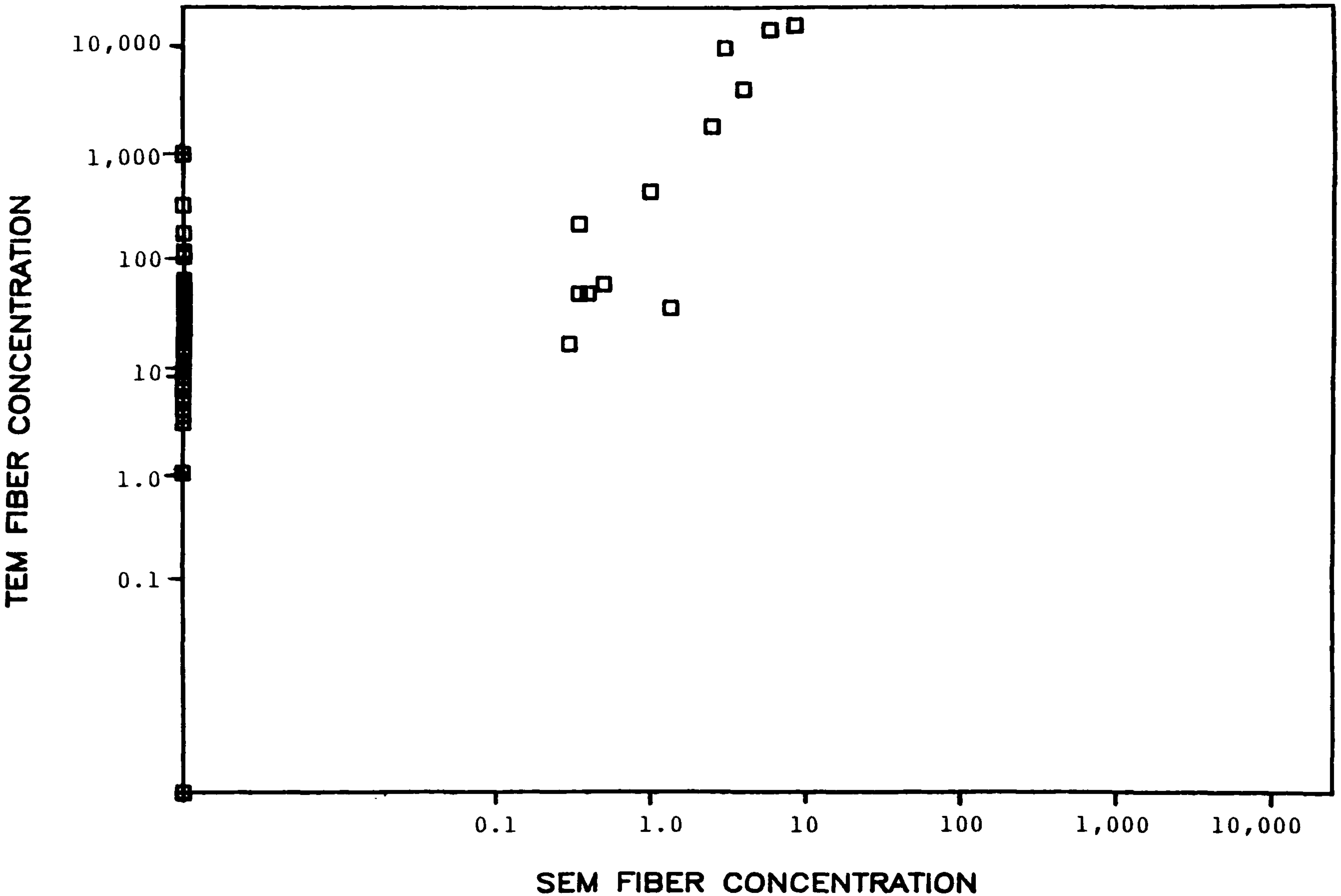


Figure 13. Fiber concentration (thousands of fibers/m^3) measured by TEM plotted against fiber concentration measured by SEM. Air samples were collected simultaneously at the same site.

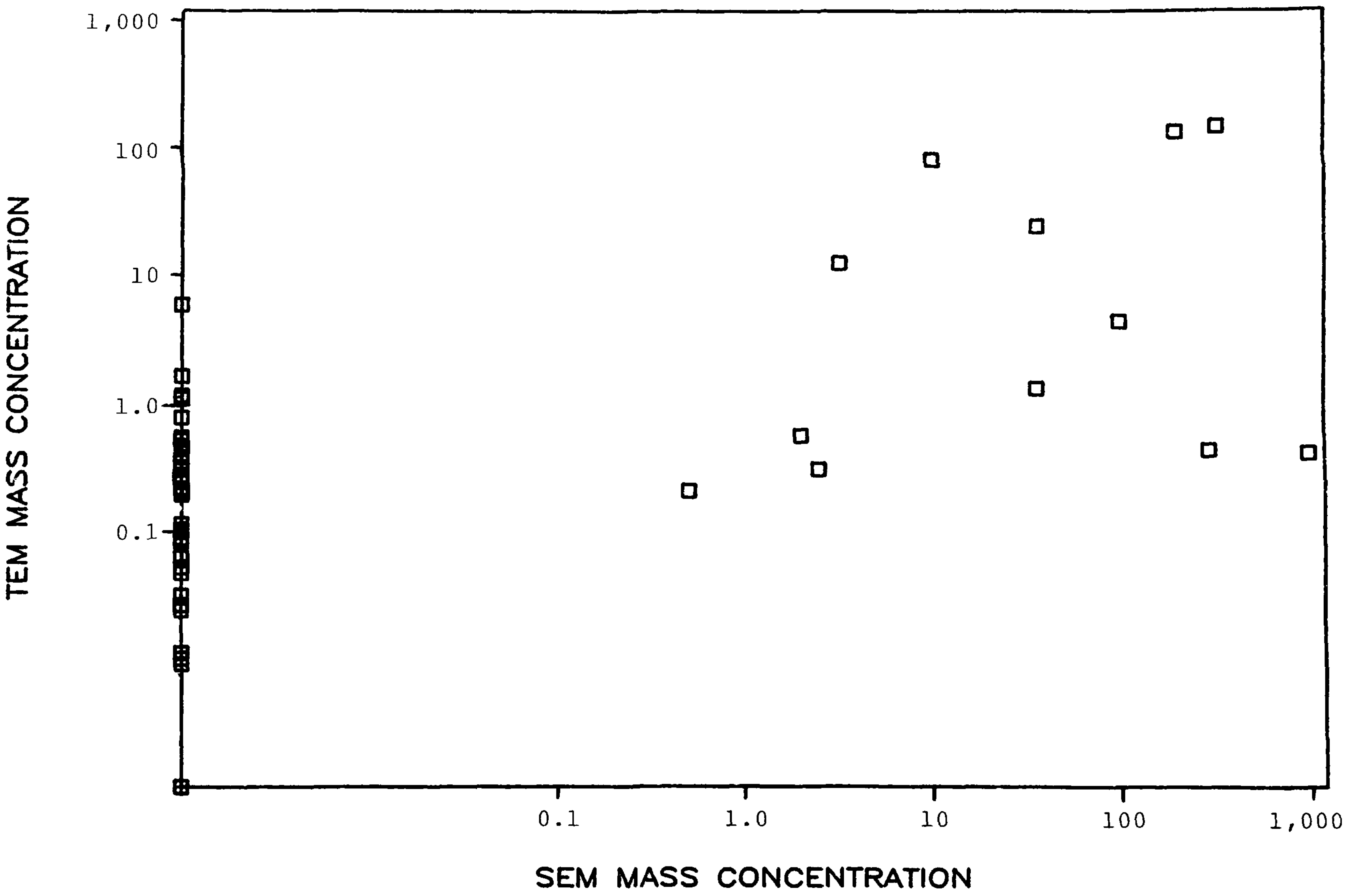


Figure 14. Mass concentration (ng/m^3) measured by TEM plotted against mass concentration measured by SEM. Air samples were collected simultaneously at the same site.

a statistically significant correlation between the TEM and SEM results. When only the nonzero SEM results are considered, the correlation coefficients are 0.91 for fiber concentration and 0.30 for mass concentration ($p = 0.0001$ and $p = 0.34$, respectively). The lack of a significant correlation between TEM and SEM mass concentrations when the zero SEM values are eliminated is caused by the small number of large fibers detected by SEM. These had a very large influence on the mass concentration for SEM with no correspondingly high value in TEM since these large fibers would have likely been recorded as bundles or clusters by TEM.

Seventy-four filters were analyzed by both TEM and PCM. Fiber concentration results are plotted in Figure 15. (Mass concentration cannot be calculated from PCM data.) The correlation coefficient of 0.07 is not significant ($p = 0.54$), indicating no significant relationship between the TEM and PCM results. When only nonzero PCM results are considered, the correlation coefficient is 0.04 ($p = 0.72$).

Both TEM and SEM give similar qualitative results for the before, during, and after abatement sampling periods: airborne asbestos levels were low before and after abatement and elevated during abatement (see Figure 11 and Section II above). Fewer fibers were counted by SEM on the Nuclepore filters (no fibers were observed on 79% of the filters) and fiber concentrations

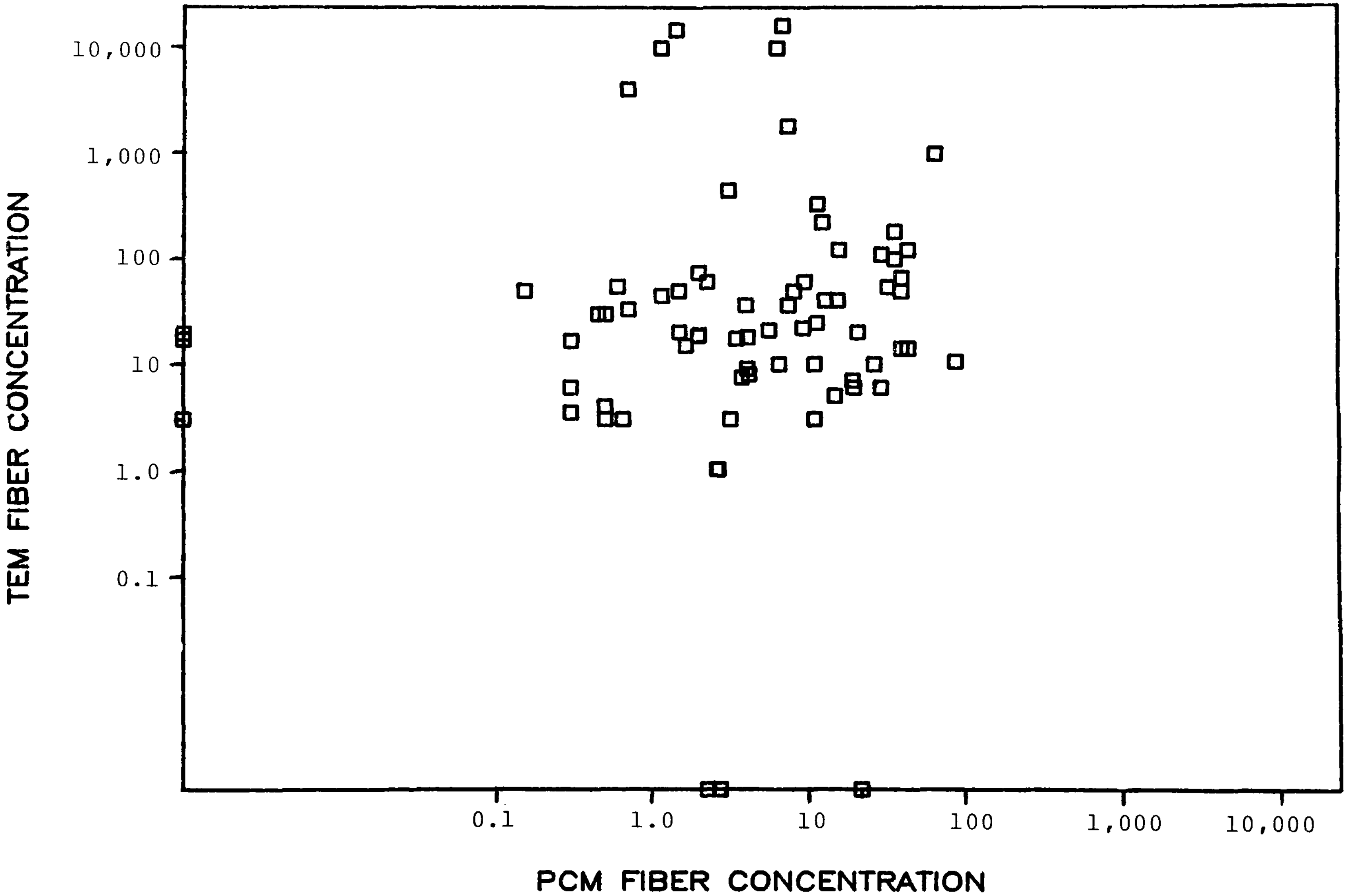


Figure 15. Fiber concentration (thousands of fibers/m^3) measured by TEM plotted against fiber concentration measured by PCM. Both analyses were done on a single filter.

were correspondingly lower (less than 1.0×10^4 fibers/m^3 compared to up to 1.6×10^7 fibers/m^3) than those obtained with TEM. This is not surprising since SEM cannot detect very small fibers that are still visible under TEM. Figure 12 illustrates the fiber size ranges that can be detected by each of the analytical methods under the conditions of this study.

Nonzero mass concentrations measured by SEM were generally higher than those measured by TEM. This occurs because the fibers that were detected by SEM tended to be large. SEM cannot detect very small fibers (< 0.1 μm in diameter). However, large fibers, which would probably be considered as bundles under TEM and therefore excluded from mass calculations, are detected by SEM and included in the calculations. These large fibers can have a big influence on the mass concentration. For example, the highest mass concentration measured by SEM (1,000 ng/m^3 at school 3, site 5 before removal) is derived from a single large fiber. Without additional information on the medical significance of the large fibers it is not clear whether they should be included or excluded from estimates of mass concentration. The detection of large fibers by SEM is not closely related to the presence of bundles or clusters in the TEM analysis. TEM detected bundles or clusters in 26 of the 60 SEM/TEM sample pairs. SEM detected one or more fibers in 9 of the 26 cases and in 3 of the remaining 34 cases.

The difference in the number of fibers detected by TEM and SEM may also be attributable in part to the fact that different types of filters were used (Millipore for TEM and Nuclepore for SEM). It is thought that the fibers may be lost more readily from Nuclepore filters because of their slippery surface, although the evidence for this is questionable. Analyzing both types of filters by both methods would help to resolve the question.

Fiber concentrations estimated by PCM did not follow the same pattern, with respect to sampling period, as those estimated by TEM or SEM. The highest concentrations were at indoor sites before abatement and after school had resumed--the two periods of greatest activity in the schools. The PCM fiber concentrations tended to be higher (0 to 1×10^5) than levels obtained by SEM (less than 1×10^4) but lower than those obtained by TEM (up to 1.6×10^7). Recall that PCM provides a total fiber count which does not distinguish asbestos from nonasbestos fibers.

The restricted range of air levels found in this study does not allow a complete comparison of the three different analytical methods. In this particular case, where levels are generally low, TEM appears to provide the most complete description of the course of events. SEM results show a similar pattern, but only a small number of asbestos fibers were detected and mass concentrations were determined by a few large individual fibers. PCM provides no indication of the elevated airborne asbestos levels during removal and bears no obvious relationship to the other measures.

IV. ANALYSIS OF RELATIONSHIPS BETWEEN BULK SAMPLES AND LEVELS OF AIRBORNE ASBESTOS FIBERS

Eight bulk samples (including two side-by-side samples) were collected from each asbestos-containing site after the first sampling period and before the removal operation took place. Four of these were analyzed by PLM and rated for releasability. The rest were stored for future use. The releasability rating is a subjective rating of the tendency of the material to release fibers (see Section II.B). It is measured on a scale of Ø to 9 with 9 indicating a very high tendency to release fibers. The average percentage by volume of chrysotile and the average releasability rating for each school and site are shown in Table 9. The average is weighted, with side-by-side samples receiving a weight of 1/6 and all other samples a weight of 1/3. Investigating the relationship between airborne asbestos levels and properties of the bulk sample was a secondary objective of the study. This was done only for air levels measured during removal since airborne asbestos levels at all schools were very low for the other three sampling periods.

Percentage chrysotile and releasability ratings are very similar (approximately 15-25% and 4-5.5, respectively) at schools 1, 2, and 3. Bulk samples from school 4 contain a higher percentage of chrysotile (84%) and the releasability rating for site 1 at school 4 is 7. The average airborne asbestos level during abatement is highest at school 4 (Table 5) and this could be

Table 9. Percent Chrysotile Content and Releasability Rating (Weighted Average) for Each Asbestos-Containing Site

		CHRYSOTILE %	RELEASABILITY
		MEAN	MEAN
SCHOOL	SITE		
1	2	23.33	5.50
	3	23.33	5.00
	5	25.83	5.17
	6	25.83	5.67
	8	25.00	5.83
2	2	20.00	5.00
	4	17 17	4.67
	5	23.00	4.67
	6	20.00	5.50
3	1	26.17	3.50
	3	24.67	5.17
	4	23.67	3.83
	6	23.33	5.67
4	1	83.33	7 17
	2	83.33	4.00

due to the nature of the asbestos material. In this school the material could not be wetted successfully and the material had to be broken with a hammer. The relationship between air levels and bulk sample properties is illustrated graphically in Figures 16 and 17. In Figure 16, average mass concentration during abatement is plotted against average chrysotile percentage for each school. The average mass concentration (ng/m^3) is obtained by taking the geometric mean of levels measured by TEM at each site immediately outside the barriers. The average chrysotile percentage is the arithmetic mean of all bulk samples taken at the school with side-by-side samples weighted as described above. Figure 17 is a similar plot using releasability ratings. Although school 4 shows the highest mass concentration, percent asbestos, and releasability, the overall relationship between asbestos concentration and properties of the bulk material is not striking. This is not unexpected since the measured levels will also depend on how well the barriers are constructed and maintained and this could vary from school to school.

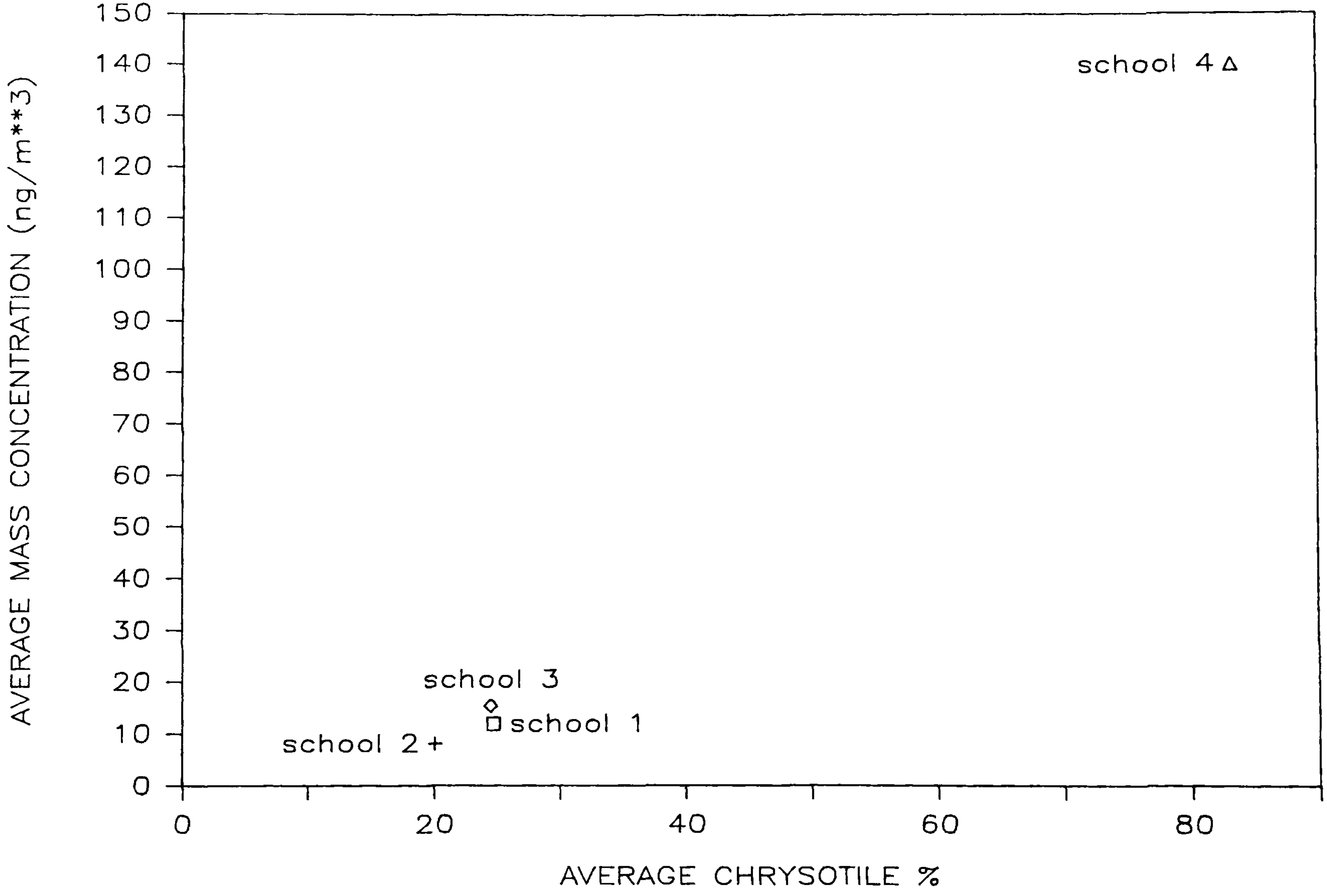


Figure 16. Average mass concentration (ng/m3) during removal plotted against average chrysotile percentage of the bulk samples for each of the four schools.

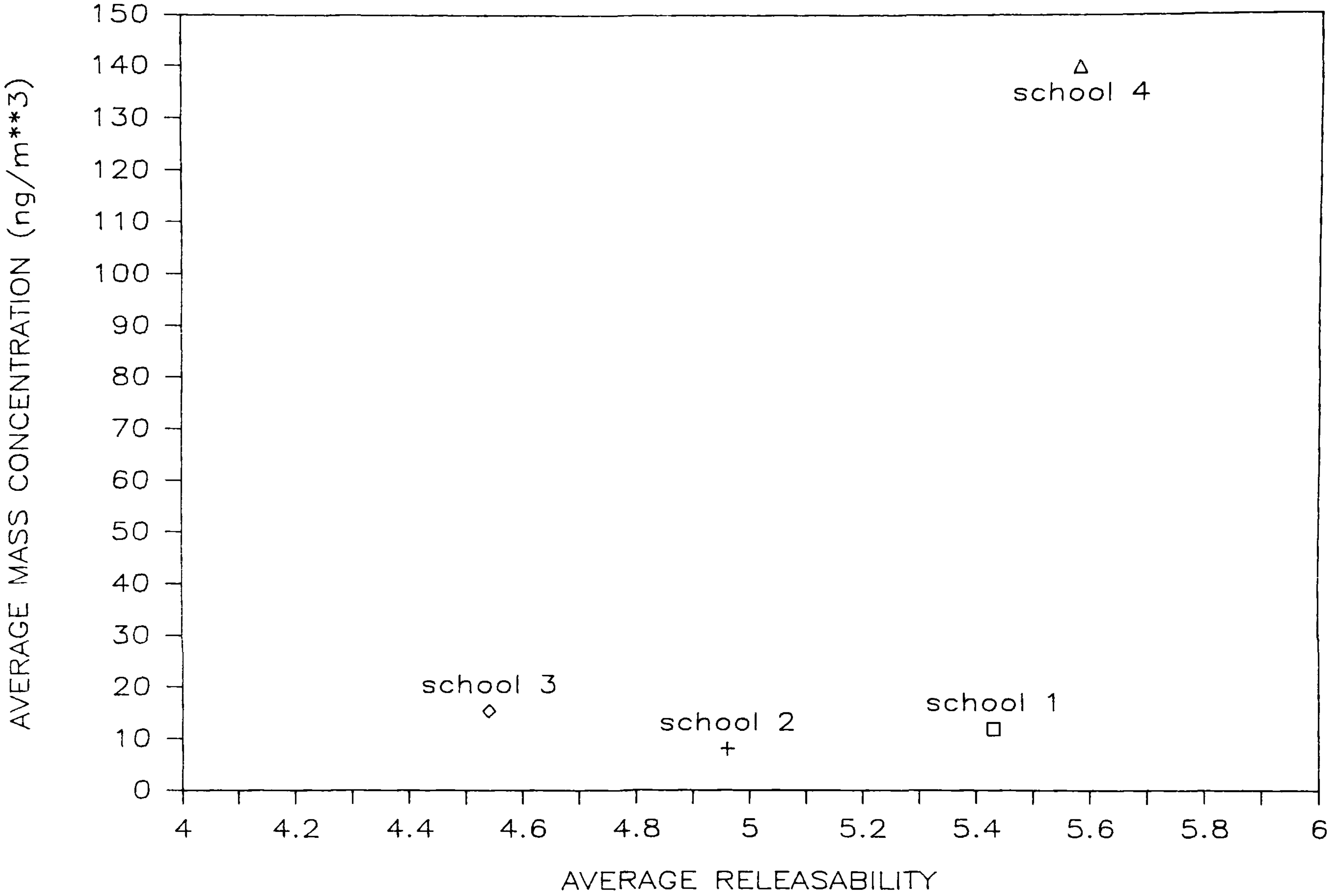


Figure 17. Average mass concentration (ng/m^3) during removal plotted against average releasability rating of the bulk samples for each of the four schools.

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Leidel NA, Bayer SG, Zumwalde RD, Busch KA. 1979. USPHS/NIOSH Membrane filter method for evaluating airborne asbestos fibers, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 79-127.

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USEPA. 1982. U.S. Environmental Protection Agency. Interim method for the determination of asbestos in bulk insulation samples. Test method. Research Triangle Park, NC: Office of Pesticides and Toxic Substances. EPA 6ØØ/M4-82-Ø2Ø.

USEPA. 1983a. U.S. Environmental Protection Agency. Guidance for controlling friable asbestos-containing materials in buildings. Washington, DC: USEPA. EPA 56Ø/5-83-ØØ2.

USEPA. 1983b. U.S. Environmental Protection Agency. Airborne asbestos levels in schools. Washington, DC: USEPA. EPA 56Ø/5-83-ØØ3.

USEPA. 1985. U.S. Environmental Protection Agency. Guidance for controlling asbestos-containing materials in buildings. Washington, DC: USEPA. EPA 56Ø/5-85-Ø24.

APPENDIX A

Excerpts From Quality Assurance Plan and Quality Assurance Data Tables

APPENDIX A-1

QUALITY ASSURANCE OBJECTIVES

The following QA objectives will apply to this project within the constraints of the techniques:

I. ACCURACY

Subject to availability, NBS standard filter preparations of known asbestos concentration will be used to assess accuracy. These standards have not been available previously, thus quantitative assessment of accuracy has not been possible.

Transmission electron microscopy (TEM) is the best available technique for measuring asbestos concentration because it provides a means of distinguishing asbestos fibers from non-asbestos fibers and allows measurement of individual fibers to contain estimates of mass concentration. Bundles or clusters of fibers are not included in the calculation of mass concentration because of the difficulty of assigning meaningful dimensions to these aggregates. Therefore, if bundles or clusters are present both Scanning electron microscopy (SEM) and TEM, like any other optical technique, will tend to underestimate the mass concentration.

Phase Contrast Microscopy (PCM) cannot distinguish asbestos fibers from non-asbestos fibers and therefore may overestimate asbestos fiber concentration.

II. PRECISION

The number of fibers counted by SEM, TEM, and PCM can be expected to range from 1 to 1,000. Thus, from 1 to 3 significant figures may be reported.

In the duplicate and replicate analyses of the SEM, TEM, and PCM methods, coefficients of variation (standard deviation divided by the mean) of the asbestos concentration are expected to be about 40% or below unless the concentrations are very low (<50 ng/m^3)[1].

In the duplicate and replicate analyses of the bulk sample analyses by PLM, the coefficients of variation are expected to be 0.60 or less[2].

III. REPRESENTATIVENESS

This QA plan specifies sample collection procedures (locations and time periods) that should assure reasonable representativeness. Samplers will be placed according to the guidelines in

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[1]Constant, P. C. et al, 1983. Midwest Research Institute, Airborne Asbestos Levels in Schools, Final Report. Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contracts 68-01-5915 and 68-01-5848.

[2]Brantly, E. P. et al, 1982. Bulk Sample Analysis for Asbestos Content: Evaluation of the Tentative Method. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency (EPA) 600/54-82-021.

Section 14.1 of the Quality Assurance Plan in order to obtain as representative an air sample as possible.

IV. COMPLETENESS

The most serious, and most difficult to control, cause of lost samples is human interference and vandalism. Sites, and placement of pumps within sites, are chosen to minimize this risk. Loss of samples due to errors by the field sampling crew should not exceed 5 to 10 percent.

APPENDIX A-2

SAMPLE CUSTODY

Standard MRI sample traceability procedures described herein will be used to ensure sample integrity.

- Each sample (filter or bulk) will be issued a unique project identification number as it is removed from the pump. This number will be recorded in a logbook along with the following information:
  - Name and signature of field operator.
  - Lot or assigned batch number (or any other identifiable number).
  - Filter type (e.g., Millipore, Nuclepore).
  - Date of record.
  - Number of school and site.
  - Position of sampler within site.
  - Use of filter, i.e., field blank, lab blank or test filter.
  - Condition of sample.
  - Sample flow rate at start of sampling period.
  - Start time.
  - Stop time.
  - Sample flow rate at end of sampling period.
  - Any specific instructions/comments.

- A traceability packing slip will be filled out in the field.
- The samples will be hand-carried to MRI where the package contents will be inventoried against the traceability packing slip.
- A copy of the inventory sheets will be sent to MRI's department management representative and QA monitor. The original will remain with MRI's field sampling leader in his project files. If sampling information is contained in the field numbers, a set of random numbers will be generated and assigned sequentially to each sample, replacing the field identification numbers. The relationship between the two sets of numbers will be recorded and a copy retained by the QAM. Warning labels (if appropriate) will be affixed.
- In order to maintain traceability, all transfers (e.g., to Battelle, QA laboratory, etc.) of samples are recorded in an appropriate notebook (where appropriate). The following information will be recorded:
  - The name of the person accepting the transfer, date of transfer, location of storage site, and reason for transfer.
  - The assigned MRI sample code number remains the same regardless of the number of transfers.

After the samples are properly logged in they will be placed in suitable storage areas. These areas will be identified as to the hazard they present to the samples.

APPENDIX A-3

SAMPLE ANALYSES PROCEDURES

All air samples, hand-carried to MRI then to the laboratory carrying out the chemical analysis, shall be kept encoded until the end of all microscopy analyses (SEM, TEM, PCM). The same procedure shall be used for bulk samples for polarized light microscopy (PLM). They shall be decoded by MRI's QA monitor after all analyses are completed. Electron microscope preparation and analysis of air samples shall be carried out according to the Analytical Protocol for Air Samples based on the U.S. EPA Provisional Methodology Manual (USEPA 1978) (see reference 1, Appendix E). For SEM analyses, the guidelines developed by Mr. Gene Brantly of Research Triangle Institute shall be followed (Appendix A). PLM analyses shall be done according to the protocol in Appendix B of reference 2, and bulk samples shall be prepared and analyzed according to the protocol given in Appendix D of reference 1. In all cases any deviations from, or elaborations of, the specified protocols shall be carefully documented.

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[1]USEPA. 1983 U.S. Environmental Protection Agency, Airborne Asbestos Levels in Schools. Office of Pesticides and Toxic Substances. Washington, D.C.: USEPA EPA 5601 5-83-003.

[2]National Institute for Occupational Safety and Health (NIOSH) Method No. P&CAM 239: Asbestos Fibers in Air.

I. FIELD BLANKS (MILLIPORE FILTERS)

From the 24 field blanks per sampling period (1 per site), 3 shall be randomly selected by MRI's QA monitor for chemical analysis for contamination check. These 3 filters shall consist of one filter from an asbestos-free room, one filter from an asbestos-containing room, and one from outdoors. The remaining 21 field blanks shall be kept for additional analyses, if necessary.

II. EXTERNAL QUALITY ASSURANCE FILTER ANALYSIS

As a quality assurance measure, MRI's QA monitor shall randomly select samples to be analyzed by an external laboratory (QA laboratory). QA analyses shall be performed for all three methods: transmission and scanning electron microscopies (TEM and SEM) and phase contrast microscopy (PCM). All filters selected for QA analysis shall be divided in half according to the analytical protocol for air samples and one half of each filter shall be hand-carried to the QA laboratory. The results from the QA laboratory will be compared with those from the primary laboratory. The filters shall be selected as follows:

- for TEM analysis (21-hr Millipore filter samples)
  - 1 from asbestos-free rooms
  - 3 from asbestos-containing rooms
- for TEM analysis (35-hr Millipore filter samples)
  - 1 from asbestos-free rooms

- 3 from asbestos-containing rooms
- 1 from outdoors

- for SEM analysis (35-hr Nuclepore filter samples)
  - 2 from asbestos-free rooms
  - 4 from asbestos-containing rooms
  - 1 from outdoors
- for PCM analysis (35-hr Millipore filter samples)
  - 2 from asbestos-free rooms
  - 8 from asbestos-containing rooms
  - 2 from outdoors.

No field blanks shall be analyzed by the QA laboratory.

III. REPLICATE AND DUPLICATE FILTER ANALYSES

As a means of quantifying in-house variability, and analytical variability introduced by the filter preparation procedure, samples shall be selected by MRI's QA monitor for replicate and duplicate analyses. Replicate analyses shall be performed using two independent preparations from the same filter. Duplicate analyses shall be conducted by a second analyst using the same grid preparation as in the original analysis. For this purpose, filters shall be randomly selected from the remaining filters (i.e., those not chosen for external QA analysis). Filters shall be selected in the same fashion for duplicate and replicate analyses for all three methods (TEM, SEM, and PCM) as follows:

- for TEM analysis (21-hr Millipore filter samples)
  - 1 from asbestos-free rooms
  - 2 from asbestos-containing rooms
- for TEM analysis (35-hr Millipore filter samples)
  - 1 from asbestos-free rooms
  - 3 from asbestos-containing rooms
  - 1 from outdoors
- for SEM analysis (35-hr Nuclepore filter samples)
  - 1 from asbestos-free rooms
  - 4 from asbestos-containing rooms
  - 1 from outdoors
- for PCM analysis (35-hr Millipore filter samples)
  - 2 from asbestos-free rooms
  - 8 from asbestos-containing rooms
  - 2 from outdoors.

IV. LABORATORY BLANKS

As a means of checking on possible contamination during the preparation procedures, laboratory blank filters should be subjected to standard laboratory procedures during preparation and analysis of the samples. At least three Millipore laboratory blank filters shall be analyzed by the main laboratory and three by the external QA laboratory for both TEM and PCM. At least one Nuclepore laboratory blank filter shall be analyzed by the main laboratory and one by the external QA laboratory for SEM.

V. BULK SAMPLE QA ANALYSIS

The recommended number of bulk samples to be taken from sites of this size is three[1]. However, since the asbestos-containing material is about to be removed and the collection of additional samples is not costly, samples shall be taken from 6 locations at each asbestos-containing site. At two of the 6 locations a pair of side-by-side samples shall be taken for QA analysis giving a total of 8 samples per site. Only half of the samples shall be analyzed. The remainder shall be stored for possible future use.

From the 8 bulk samples per site, 4 samples shall be randomly selected by MRI's QA monitor and released to MRI for analysis using PLM techniques. These 4 samples shall be selected in such a way as to obtain 2 side-by-side samples and 2 samples which are not side-by-side. This will result in 15 pairs of side-by-side samples and 30 other samples being selected.

Quality assurance analysis of 8 bulk samples shall be done by a laboratory other than MRI. Eight pairs of samples shall be selected from the 15 pairs of side-by-side samples. One member

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[1]"Asbestos-Containing Materials in School Buildings: Guidance for Asbestos Analytical Programs", by D. Lucas, G. Hartwell and A. V. Rao. December 1980. USEPA Office of Toxic Substances, Washington, D.C.

of each pair shall be analyzed at MRI; the other member shall be analyzed at the QA laboratory. The remaining 7 pairs of side-by-side samples shall be analyzed at MRI to provide replicate laboratory analyses. In addition, 7 bulk samples shall be analyzed by two different analysts within MRI (duplicate analyses).

The remaining bulk samples shall be stored and can be analyzed later if the results of the sample or QA analyses indicate that this will be useful or desirable.

APPENDIX A-4

ROTAMETER CALIBRATION PROCEDURES AND REFERENCE MATERIALS

I. ROTAMETER CALIBRATION PROCEDURE

(1) Record the preliminary data at the top of the data sheet shown in Figure 1.

(2) Set up the calibration system as shown in Figure 2. Allow the wet test meter to run for 20 minutes before starting the calibration.

(3) Turn on the pump and adjust the flow until the pyrex ball is around 25 on the rotameter scale.

(4) Record both the stainless steel and pyrex ball values on the data sheet.

(5) Measure the volume of air which passes through the rotameter during an accurately timed interval. Record the initial and final times and wet test meter readings.

(6) Record the wet test meter temperature (Tw) and manometer readings (ΔP) during the time interval.

(7) Run at least duplicates for each rotameter setting.

(8) Reset the pyrex ball to around 90 and repeat Steps 4 through 7.

(9) Reset the pyrex ball to around 120 and repeat Steps 4 through 7.

Flowmeter type ______________ Tube ______________

MRI or I.D. no. ______________ Date ______________

Barometric pressure, Pb ______________ "H_2O Initial ______________

Standard pressure, Ps ______________ "H_2O Standard temp, Ts ______ °C

Test no.	Flowmeter ball, mm		Wet test meter (corr. =)					Q^b
	SS	Pyrex	Time min	Vw cc	ΔP "H_2O	Tw °C	Vp[a] "Hg	Flowrate Std cc/min

[a] From vapor pressure vs. temperature tables

$$^{b}Q = \frac{(Vw \times Corr.)}{Time}\left[\frac{(Pb - Vp) + \left(\frac{\Delta P}{13.6}\right)}{Ps}\right]\left(\frac{Ts}{Tw + 273}\right)$$

Figure A-1. Flowmeter calibration dataform, > 1000 cc/min.

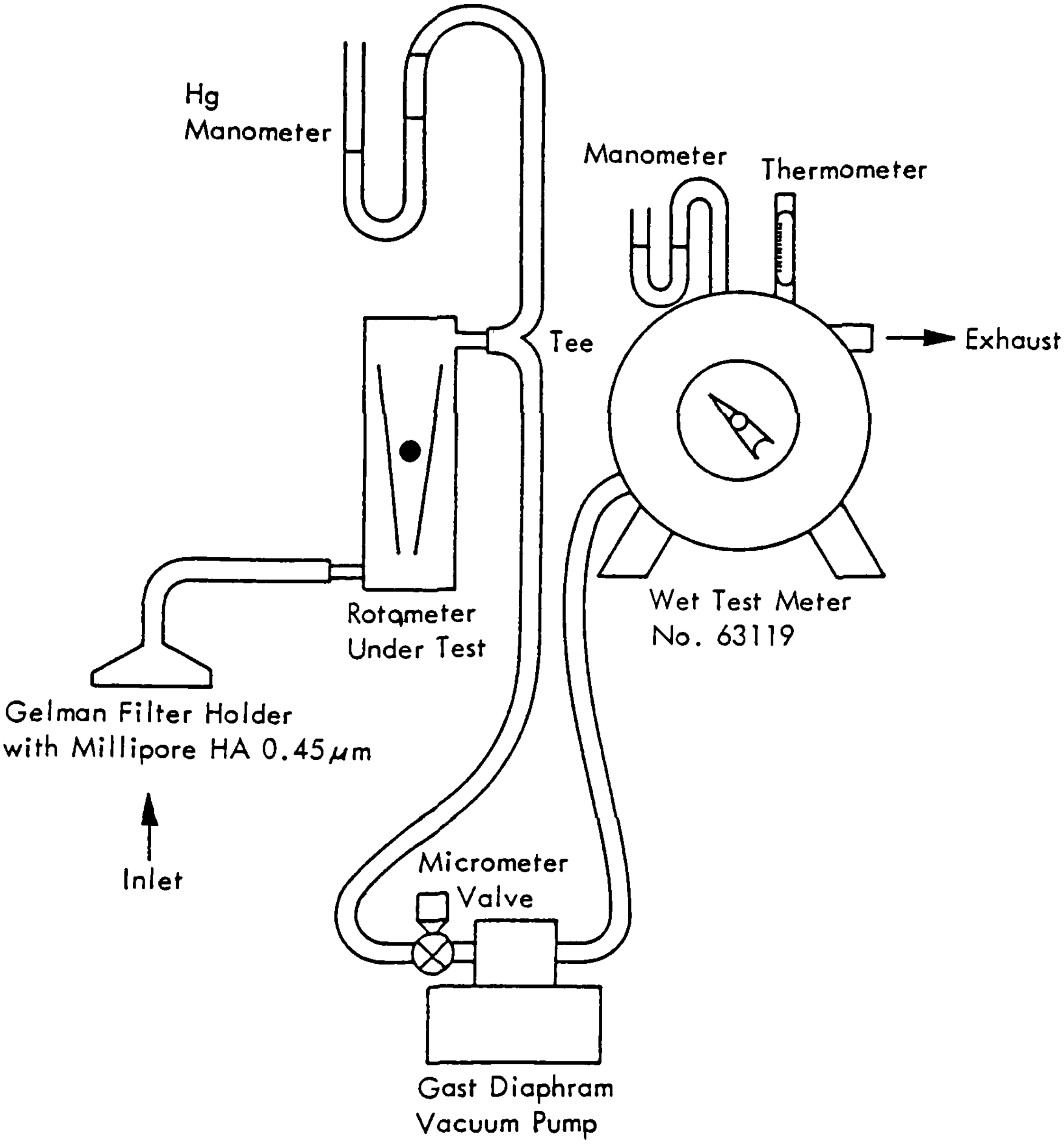


Figure A-2. Rotameter calibration system.

(10) Calculate the flow rates for each setting using the equation:

$$Q = \frac{Vw \times Corr}{Time} \quad \frac{(Pb - Vp) + \Delta p/13.6}{Ps} \quad \frac{Ts}{Tw + 273}$$

where:

Q = flow rate in standard cc/min,

Vw = wet test meter volume in cc,

Corr. = correction value obtained for each specific wet test meter,

Time = time in minutes,

Pb = barometric pressure in inches of H_2O

Vp = vapor pressure in inches of Hg,

Δp = manometer reading in inches of H_2O

Ps = standard pressure in inches of H_2O

Ts = standard temperature in °K, and

Tw = wet test meter temperature in °C.

(11) Plot rotameter readings versus values for Q for each setting as shown in Figure 3.

II. ROTAMETER CALIBRATION SCHEDULE

The rotameters shall be checked, cleaned if necessary, then calibrated prior to the first sampling trip.

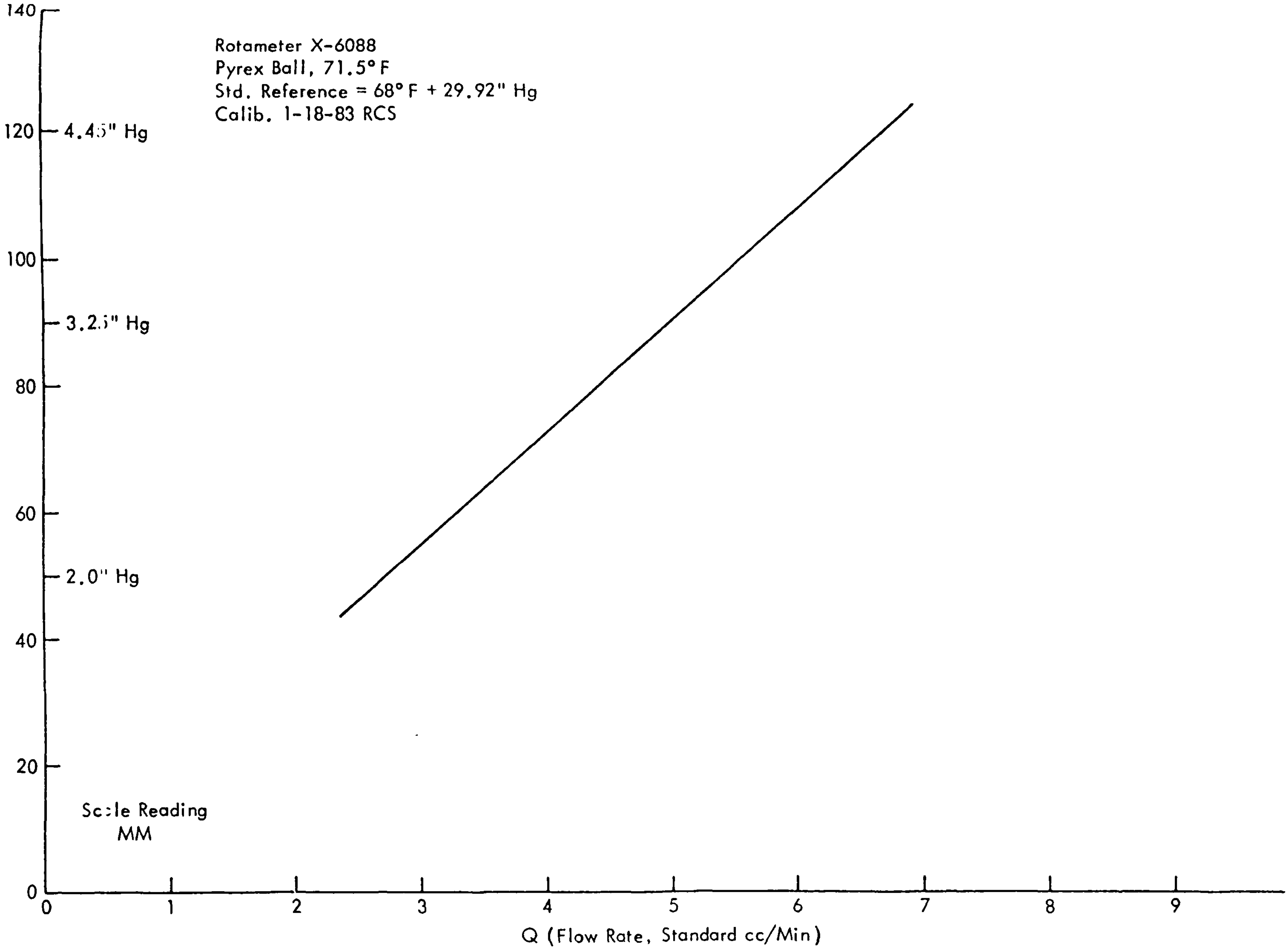


Figure A-3. Plot of rotameter readings versus values of Q.

III. REFERENCE MATERIALS

Standard materials of known asbestos type shall be used as reference for fiber morphology and electron diffraction patterns.

APPENDIX A-5

STATISTICAL DATA HANDLING

I. DATA VALIDATION

As a minimum, the guidelines listed below should be followed:

- When calculations are made by hand, 2 people shall spot check some calculations independently and then compare results; correct, if necessary.

- When computer is used, data entry shall be verified; programs, formulae, etc..., shall be tested with sample data previously worked out by hand.

- When statistical software packages are used, tests of reason shall be applied; on outputs, double-check sample sizes, degrees of freedom, variable codes, etc...; be alert for outliers.

- When reporting numerical results, computer generated outputs rather than retyped tables shall be used to the extent possible. When possible, reported tables shall be compared for consistency in variable codes and values, sample sizes, etc...

In all cases, data validation activities shall be documented and records kept of any necessary corrective action in the appropriate notebook.

II. DATA PROCESSING AND ANALYSIS

As data become available from the chemical analyses they shall be entered into computer files. The files shall be checked against the raw data for accuracy. Graphical displays and summary statistics shall be generated. Comparisons shall be made between asbestos concentrations at asbestos and non-asbestos containing sites and among different sampling periods (before, during, and after asbestos removal) using analysis of variance techniques. If necessary, transformations of the data shall be made to achieve homogeneity of variance.

Samples taken over 3- and 5-day periods shall be compared both in terms of actual concentration values and with respect to changes in concentration over time. This will provide information about the effect of sampling time on both the quantitative and qualitative aspects of the assessment of asbestos concentration.

Samples analyzed by TEM, PCM, and SEM shall be compared by calculating correlation coefficients and estimating constant and relative biases for each method relative to the other. For TEM and PCM a direct comparison will be available since each 5-day

Millipore filter will be analyzed by both TEM and PCM. Samples collected simultaneously on Millipore and Nuclepore filters on a single pump will provide comparisons between SEM and the other two methods.

The relationship between air levels and properties of the bulk samples shall be investigated. The types of analyses will depend on the range of asbestos materials present. If the materials prove to be very homogeneous then only limited analysis will be carried out.

APPENDIX A-6

PERFORMANCE AND SYSTEM AUDITS

Performance and system audits provide the primary means for external monitoring for this project. These audits will be performed during each sampling period.

Both performance and system audits will be conducted on site.

I. PERFORMANCE AUDITS

Device to be Audited	**Audited Device**
Diaphragm pump	Calibrated rotameter

* Performance Audit Procedure
  - Verify calibration of the rotameter against standard reference device.
  - Review EPA standard methods and/or other test protocols.
  - Carefully pack equipment for shipment (if applicable).
  - Directly measure flow rate against rotameter.
  - Record all data on performance audit form. In general, all reported values should be

within ± 10% as compared to the audit device.

- Prepare and submit a summary report and all records to MRI's QA department.

II. SYSTEM AUDIT

Area to be Audited	Audit Mechanism
Entire Sampling Procedure	Standard Audit Form

* System Audit Procedure

- Review test procedures and protocols.
- Obtain standard audit form.
- Observe the performance of each task.
- Ask questions as required.
- Take corrective actions as necessary.
- Fill in appropriate blank lines on audit form.
- Prepare and submit summary report, and all records to MRI's QA department.

APPENDIX A-7

QUALITY CONTROL AND CORRECTIVE ACTION

I. INTERNAL QUALITY CONTROL CHECKS

Internal quality control is achieved by the use of:

- laboratory blanks (filters)
- field blanks (filters)
- external laboratory QA analyses
- replicate analyses
- duplicate analyses
- data entry checks
- data transfer checks

as described in Sections 14, 16, and 18.

II. FEEDBACK AND CORRECTIVE ACTION

The types of corrective action procedures which will be used for this program are:

- On-the-spot, immediate, corrective action.
- Closed-loop, long-term, corrective action.

A. On-the-Spot Corrective Action

This type of corrective action is usually applied to spontaneous, non-recurring problems, such as instrument malfunction. The individual who detects or suspects nonconformance to previously established criteria or protocol in equipment, instruments, data, methods, etc., immediately notifies his/her supervisor. The supervisor and MRI task leader then investigate the extent of the problem and take the necessary corrective steps. If a large quantity of data is affected, the supervisor and task leader must prepare a memo to the program manager, the Quality Assurance monitor, MRI's QA manager, and the QA administrator. These individuals will collectively decide how to proceed. If the problem is limited in scope, then the task leader decides on the corrective action measure, documents the solution in the appropriate workbook, and notifies the QAM, MRI QA manager and the QA administrator in memo form.

B. Closed-Loop, Long-Term Corrective Action

Long-term, corrective action procedures are devised and implemented in order to prevent the re-occurrence of a potentially serious problem. The QAM is notified of the problem. She/he then conducts an investigation of the problem to determine its severity and extent. The QAM then files a corrective action request with the appropriate Task Leader, with a copy to MRI's QA manager, requesting that corrective measures be put into place. Suggestions as to the appropriate corrective action will also be made. The Task Leader is responsible for implementing any corrective actions. The QAM will conduct a follow-up investigation to determine the effectiveness of the corrective action.

APPENDIX B

Sampling and Analysis Protocols

APPENDIX B-1

AIR SAMPLING PROTOCOL

Airborne asbestos sampling will be conducted according to the general procedure outlined in Reference 1. This will involve samples taken at both indoor and outdoor sites as specified in the sampling plan.

All samplers will be equipped with a timing device and set to operate during hours of normal school activity over a period of a week. The collection substrate will be 47 mm 0.45 μm cellulose acetate (Millipore type HA) filters and 37 mm 0.2 μm Nuclepore filters.

I. SELECTION OF SAMPLING LOCATION

A. Sites: Once a site has been identified, the sampling system must be located to give a representative sample of the entire site within practical constraints. If possible, the filter should be placed at a height of approximately 1.5 m (59 in.). It should be placed in a location which minimizes disruption of normal activity. Positions close to walls or windows should be avoided, if practical. Attention should also be given to insure that the sampler in operation does not create a unsafe situation (e.g., extension cord across a doorway).

B. Outside ambient: The location of the outside ambient sampler is important to obtain a representative background measure. This sampler, thus, should be placed upwind of the building it is to represent such

[1]"Airborne Asbestos Levels in Schools: A Design Study," by B. Price, C. Melton, E. Schmidt, and C. Townley, dated November 20, 1980, a special project report prepared by Battelle's Columbus Laboratories under EPA Contract No. 68-01-3858.

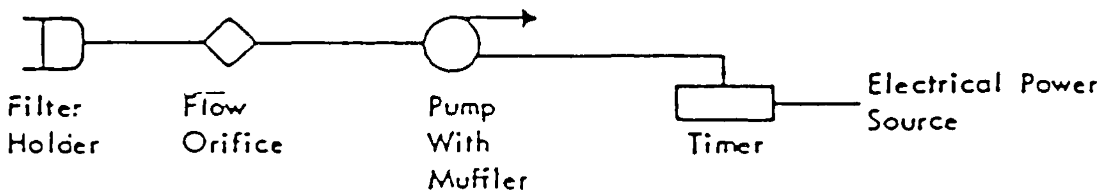
that no bias is created by identifiable local sources (e.g., parking lots, highways, and building exhaust). With regard to the above considerations, as well as power requirements and anticipated accessibility to vandals, the upwind side of a building roof may be the most desirable location.

II. SAMPLER SETUP

The sampling system consists of:

1. An open-face filter holder.
2. A control flow orifice.
3. A pump with muffler.
4. Associated plumbing and stand.
5. A method of measuring sampling time.

The sampler setup is schematically represented as follows:



III. SAMPLING PROTOCOL

1. Clean and dry filter holder and place in horizontal position.

2. Place filter in holder, assuring proper position (see filter handling section) and clamp filter in place.

3. Rotate filter holder such that filter is in a vertical position (perpendicular to ground).

4. Check plumbing for any leaks and check filter holder to assure that it is free from fibration.

5. Check flow with flowmeter with the timer control set on manual.

6. Set automatic timer to correct date and time and set on/off trippers to desired on-off time settings.

7. Make appropriate logbook entries.

8. Conduct sampling.

9. Rotate filter to horizontal position, check flow, stop pump and remove filter. Place Millipore filter in petri dish, number petri dish, and cover Nuclepore filter cassette with lid for proper handling and transport.

IV. FILTER HANDLING PROCEDURES

1. Handle the filters by forceps (not with fingers) during loading and unloading of the filter holders.

2. After sampling, place the exposed filter in the petri holder (Millipore filters) exposed side up and maintain in that position during the handling and transport of the samples to the laboratory.

3. Hand-carry the samples in a container at the end of each sampling period to MRI by MRI field personnel.

4. Handle the container in a way that will keep the petri holders and the Nuclepore filter cassettes in a horizontal (flat) position at all times (handling, transport, and storage).

V. LABORATORY BLANKS

Use filters from the same production lot number, if possible. Prior to field sampling, select one filter per box of 25 Millipore filters, to serve as laboratory blanks and keep at MRI until analysis. A similar proportion of Nuclepore filters shall be kept as laboratory blanks.

VI. FIELD BLANKS

During each of the four sampling periods, randomly select one field blank (filter) from a new box of filters at each sampling site. Encode and handle the blank filters according to the same protocol as the test filters.

VII. LOG BOOK ENTRIES

An important part of any field program are the observations and accurate records of the field team. As a minimum, logbook entries shall include:

1. Name of field operators.
2. Date of record.
3. Site number and location (school and site).
4. Tag numbers of pump, timer, and filter holder (G - XXXX- EPA).
5. Relative humidity and temperature inside building and outside.
6. Position of sampler within site (coordinates).
7. Brief site description (sketch).

8. Corresponding filter number (assigned at end of sampling period).

9. Sample flow rate at start of sampling period for each filter head.

10. Settings of timer clock (on-off tripper positions).

11. First day of sampling (date).

12. Sample flow rate at end of sampling period.

13. Comments.

14. Photographs--overview, to left, to right and ceiling overhead or sampler.

15. Running time meter reading.

VIII. POST SAMPLING PROCEDURE

1. Measure the flow.

2. Check filter condition and location (coordinates) of the sampler.

3. Record day of week and time position of the timer clock.

4. Record the time on the running-time meter or alarm clocks used as lapse-time clocks.

5. Record the relative humidity and temperature inside the building and outdoors.

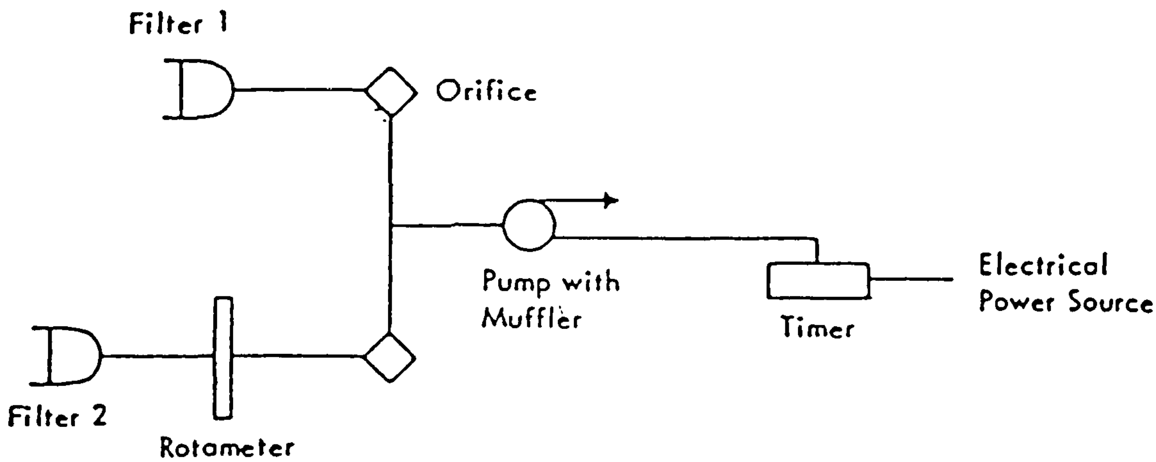
If possible, conduct a midweek site check of points 1-5.

Note: At some time before equipment is removed from a school, obtain and record information from the head custodian on how the school is cleaned (e.g., dry-mopped, wet-mopped, swept with bristle broom, daily, etc.).

IX. PROCEDURE FOR MEASURING FLOW IN THE FIELD

This procedure describes the process used to determine the sample flow rates through the filters used to collect fibers in ambient air.

1. Set up the sampling system as shown below with the rotameter in one leg of the sampler.



2. Turn on the pump and with both filters in place, record the rotameter reading in the notebook.

3. Turn off the pump and transfer the rotameter to the other leg of the sampler.

4. With both filters in place, turn on the pump and again record the rotameter reading for the second leg.

5. Turn off the pump and remove the rotameter from the sampler.

6. Reconnect all tubing.

7. The sampler is ready to operate.

8. Repeat procedures 1 through 5 at the end of the sampling period.

Note: A similar procedure is used for pumps equipped with only one filter holder.

9. Calculate the flow as follows:

   a. Using the calibration curve for the rotameter, determine the flow rates for each rotameter reading and record these values on the data sheet.

   b. Calculate the average flow rate for the sampling period using the following equation:

$$\text{average flow rate} = \frac{(\text{initial flow rate} + \text{final flow rate})}{2}$$

   c. Calculate the actual volume of air sample collected by multiplying the average sample rate by the sampling time.

APPENDIX B-2

PROTOCOL FOR THE SAMPLING AND ANALYSIS OF INSULATION MATERIAL SUSPECTED OF CONTAINING ASBESTOS

Bulk samples of asbestos-containing material will be taken at a site. The specific points where these samples will be taken will be designated by Battelle Columbus Laboratories (BCL)

I. Sampling

The bulk sampling procedure will be based on that presented in EPA document entitled, "Asbestos-Containing Materials in School Buildings--Guidance for Asbestos Analytical Programs" (USEPA 1980). The number of sites, the number of samples to be taken at each site, and the number and location of side-by-side samples to be taken will be designated by BCL and EPA. The side-by-side procedure eliminates the necessity of splitting samples at a later time for purpose of external quality assurance analysis.

A random identification number will be assigned to each sample. This number will also appear on the sampler container and in the field log-book along with discriptive information.

II. Sample Handling

The samples will be hand carried by the field crew to MRI with a chain of custody record. At MRI, they will be handed over to the MRI work assignment leader. The samples will be given to the microscopist for blind analysis. From each pair of side-by-side samples, one sample will be chosen and these samples hand carried to an external laboratory for quality assurance analysis.

III. Analysis

The samples will be analyzed by polarized light microscopy (PLM) including dispersion staining. Fiber identification will follow that given in the EPA "Interim Method for the Determination of Asbestos in Bulk Insulation Samples" (USEPA 1982) and that published in the Federal Register. The procedure is Summarized in Figure B-1.

IV. *Quality Assurance*

As a quality assurance measure, one sample of each set of side-by-side samples will be selected and analyzed by an external quality assurance laboratory. As a means of quantifying in-house variability, and analytical variability, a number of samples, equivalent to the one of external QA samples, will be selected for replicate and duplicate analyses. All samples for analysis will have no identification other than the random identification number. The samples not analyzed will remain at MRI.

MOUNT A REPRESENTATIVE SAMPLE IN CARGILLE HIGH DISPERSION LIQUID n_D = 1.550

ISOTROPIC

GLASS WOOL (106)[a]
Straight uniform diameter cylinders, λ_0 > 700 nm

MINERAL WOOL (111)
"Exotic" shapes, fibers variable n (1.50–1.70)

PUMICE (226)
Fire-polished flakes with vesicles, λ_0 >> 700 nm

PERLITE (529)
Thin glass films, foamed glass bubbles, λ_0 >> 700 nm

DIATOMS (5)
Organized, pitted, flat, sometimes elongated, λ_0 >> 700 nm

ANISOTROPIC

FIBROUS

CHRYSOTILE (122)
λ_0 = 600–700 nm (blue $\perp$ length; 500–600 ($\parallel$)

WOOD FIBERS (70–73)
Blue ($\perp$ length), yellow ($\parallel$ length), pitted

POLYESTER (100)
Cylindrical, high birefringence
$n_\parallel$ = 1.71, $n_\perp$ = 1.54

n's > 1.55 (pale yellow colors)
Mount in 1.605 HD liquid

> 1 λ_0 < 700 nm

TREMOLITE (205)
Oblique extinction view (15–20°) usually shows yellow ($\parallel$) and blue ($\perp$); $\parallel$ extcn.: yellow ($\parallel$), magenta ($\perp$)

ANTHOPHYLLITE (121)
All views $\parallel$ extcn., usually pale yellow ($\parallel$); golden-yellow to blue-magenta ($\perp$)

ACTINOLITE (671)
Like tremolite, but all λ_0's < 450 nm

WOLLASTONITE (735)
Not so fibrillar, λ_0's (480–530 nm), (+) and (-) elongation

All λ_0's < 400 (yellows); mount in 1.67

AMOSITE (120)
Yellow ($\parallel$ length) lavenders and blues ($\perp$ length), (+) elongation

mount in 1.68

CROCIDOLITE (123)
Yellow ($\parallel$ length), golden yellow ($\perp$ length), (-) elongation; pleochroic: gray-blue ($\perp$) and blue ($\parallel$) with one polar and no stops

NON-FIBROUS

λ_0 700 nm) (pale blues)

GYPSUM (151)
Low birefringence, often tabular with oblique extinction

λ_0 Colors in visible

QUARTZ (183)
Glassy flakes, ω (blue), ε (blue-magenta)

LIZARDITE (710)
Lamellar aggregates, undulose extinction, blues and magentas

ANTIGORITE (117)
Yellow ($\parallel$) to golden magenta ($\perp$) rods

VERMICULITE (207)
Very thin sheets, nearly isotropic, λ_0's in yellow, turned up edges usually give blue crosswise, yellow lengthwise but n's vary

λ_0's < 400 (ω) (pale yellows, white)

CALCITE (133)
Very high birefringence

DOLOMITE (140)
Like calcite, ω = 1.679

MAGNESITE (164)
Like calcite, ω = 1.694

TALC
Lamellar aggregates, pale yellows, plate view; blue ($\perp$ plate)

ALL DISPERSION COLORS GIVEN ARE FOR THE CENTRAL STOP

a. The Particle Atlas, Vols. II and III by Walter C. McCrone, et al.
Note: The source of this information is The Asbestos Particle Atlas, Ann Arbor Science Press (1980).

Figure B-1. Procedure for PLM analysis of asbestos materials.

REFERENCES

Asbestos: Friable Asbestos-Containing Materials in Schools; Identification and Notification, Appendix A. Final Rule, Environmental Protection Agency, 40 CFR Part 763, Federal Register Vol. 47, No. 103, May 27, 1982.

McCrone, W. C. 1980. The Asbestos Particle Atlas. An Arbor, MI: Ann Arbor Science, 122 pp.

USEPA. 1980. U.S. Environmental Protection Agency. Office of Toxic Substances. Asbestos-containing Materials in School Buildings: Guidance for Asbestos Analytical Programs. Washington, D.C.: USEPA. EPA 560/13-80-017A. PB81-24358 6.

USEPA. 1982. U.S. Environmental Protection Agency. Environmental Systems Laboratory. Interim Method for the Determination of Asbestos in Bulk Insulation Samples. Research Triangle Park, NC. EPA 600/M4-82-020.

APPENDIX B-3

SAMPLE CUSTODY

Standard MRI sample traceability procedures described herein will be used to ensure sample integrity.

* Each sample (filter or bulk) will be issued a unique project identification number as it is removed from the pump. This number will be recorded in a logbook along with the appropriate information.

* A traceability packing slip will be filled out in the field.

* The samples will be hand-carried to MRI where the package contents will be inventoried against the traceability packing slip.

* A copy of the inventory sheets will be sent to MRI's department management representative and QA monitor. The original will remain with MRI's field sampling leader in his project files. If sampling information is contained in the field numbers, a set of random numbers will be generated and assigned sequentially to each sample replacing the field identification numbers. The relationship between the two sets of numbers will be recorded and a copy retained by the QAM. Warning labels (if appropriate) will be affixed.

* In order to maintain traceability, all transfers (e.g., to Battelle, QA laboratory, etc.) of samples are recorded in a appropriate notebook (where appropriate). The following information will be recorded:

- The name of the person accepting the transfer, date of transfer, location of storage site, and reason for transfer.

- The assigned MRI sample code number remains the same regardless of the number of transfers.

* After the samples are properly logged in, they will be placed in suitable storage areas. These areas will be identified as to the hazard they present to the samples.

LABORATORY CUSTODY OF SAMPLES FOR ANALYSIS

The Field Custodian or designate will be responsible for transporting the packaged samples and traceability form(s) directly to the Laboratory or Sample Custodian. Upon receiving the sample filters enclosed in the labelled holders, the Lab Custodian will inspect the sample to make certain that it is still intact. The Lab Custodian will reconcile sample label and traceability form and also inspect the physical condition of the as-received samples. This information will be recorded on the form and in the Lab Record Book. Once the samples are relinquished to the Lab/Sample Custodian, the signed form will remain with that person.

The samples will then be logged into a permanent Laboratory Record Book used specifically for the project. The field collection sample number will be recorded and this number will be used throughout the sample analysis procedures.

Sample Custody After Analysis

After analysis the Laboratory Analyst will return unused portions of filter samples, analytical data forms and pertinent sample analysis data to the Sample Custodian. The traceability form will show the transfer of samples. The Lab Custodian will then make photocopies of the analytical data from each filter sample. The copies will be submitted to the Project Leader to prepare for data analysis and reporting.

Traceability forms and remaining filter portions will then be archived by the Laboratory Custodian for future reference or until a directive to return the samples to the Contractor is given.

TEM ANALYTICAL PROTOCOL FOR AIR SAMPLES

1. Select one filter from each box of 25 0.45 μm, 47 mm Millipore HA membrane filters to serve as laboratory blanks. Use all filters from the same production lot number, if possible. Determine that the laboratory blank filters are asbestos free by ashing followed by transmission electron microscope examination prior to field sampling. Record filter box and lot number.

2. Upon receipt of filters from the sampling team, record them in a laboratory record book, noting specific sample log number, date received and any particular macroscopic identifying characters for a particular filter sample. This includes damaged or smudged areas on the filter surface, lack of uniform sample deposition, attached particulate or debris, unusually heavy-appearing deposit concentration, etc.

3. Measure the diameter of the effective filter area precisely. Any damaged areas removed prior to sample preparation should be mounted on glass slides with double-stick tape and carefully measured. The total effective filter area and damaged areas of sample removed should be accurately recorded for purposes of calculation procedures.

4. A 90 degree radial section of the original 47 mm filter sample is cut in the original sample dish with a clean, single-edged razor blade. The quarter section is transferred with stainless steel forceps to a clean, one by three inch glass slide where it is cut again into smaller pie-shaped wedges to fit into the glass ashing tube (approximately 15 mm diameter by 150 mm long). Transfer the wedges by forceps to clean, numbered ashing tubes. The tubes are then placed in a LFE 504 low temperature plasma oven, with one sample tube and one laboratory control tube per ashing chamber. The lab control tube may contain either a blank Millipore filter or be run as an empty tube. The ashing process is maintained at 450 watts for two hours.

5. Upon removal from the LTA 504, the ashing tubes are treated as follows. The tube is placed in an ultrasonification bath. One to two mls of 0.22 μm filtered Millipore-Q water are poured into the tube from a clean 100 ml graduated cylinder. The sample is then sonicated vigourously for ∿ five minutes and subsequently transferred to a clean 150 ml glass beaker. The tube is then rinsed by additional untrasonification 2-3 times more using a few mls of filtered water each time and the contents then transferred to a 150 ml sample beaker. The remaining volume (up to 100 mls) of filtered water is added and the entire suspended sample or blank is sonicated again, so that the total time of dispersion in the sonicator is a minimum of 20 minutes. A clean rod is used to stir the suspended sample while it is being sonicated.

6. The 100 ml fraction is divided into three aliquots: 10, 20 and 70 ml, prepared in that order. Using a 25 mm Millipore filter apparatus, place 0.2 μm Nuclepore polycarbonate filter on top of an 8.0 μm mixed cellulose ester Millipore back-up filter. Wet the filters by aspirating ∿ 10 ml filtered DI water. Stop aspiration, pour in the first sample aliquot or portion thereof and begin the aspiration procedure again. Carefully add the remaining sample volume without disturbing the flow across the Nuclepore filter surface. The suspended sample may be resonicated or stirred between filtration of the aliquots.

7. When the sample is deposited, carefully transfer the Nuclepore filter to a clean, labelled (sample number, date and aliquot size) one by three inch glass slide. The Millipore backup filter is discarded. When dry, the 0.2 μm Nuclepore filter is tautly attached to the slide on four edges with transparent tape, leaving a small portion of each filter corner untaped. The filter is then coated withan approximately 40 nm thick carbon film (National Spectroscopic Laboratories carbon rods) by vacuum evaporation. The film thickness need only be sufficient to provide support for the deposited sample.

8. Transfer of the polycarbonate filter deposit to a 200 mesh electron microscope copper grid (E.F. Fullam) is achieved by first cutting a three millimeter square portion from the filter using a clean single-edged razor blade. This is placed, deposit side down, on the EM grid which, in turn, has been set upon a small, correspondingly labelled portion of lens tissue paper. The sample is then wet with a solution of four drops of 1,1,1-trichlorethane and five ml of chloroform. The film, grid and lens paper are then placed in a Jaffe dish consisting of copper screen supported on a bent glass rod in a covered 90 mm glass petri dish. Methylene chloride (Burdick-Jackson) is poured into the dish to saturate the lens paper without submersing the grid and sample. The dish remains covered at room temperature for two hours. The prepared sample is shifted to a clean petri dish with fresh methylene chloride and allowed to set for one hour making the total Jaffeing time four hours. After removing the grid from the Jaffe dish, it is allowed to dry and then is placed in a small gelatin capsule and mounted with the remaining coated polycarbonate filter for storage until analysis.

9. Starting with the 70 ml fraction filter, examine the EM grid under low magnification in the TEM to determine its suitability for high-magnification examination. Ascertain that the loading is suitable and is uniform, that a large number of grid openings have their carbon film intact, and that the sample is not contaminated excessively with extraneous debris or bacteria.

10. Scan the EM grid at a screen magnification of 20,000X. Record the length and breadth of all fibers that have an aspect ratio of greater than 3:1 and have substantially parallel sides. Observe the morphology of each fiber through the 10X binocular and note whether a tubular structure characteristic of chrysotile asbestos is present. Switch into SAED mode and observe the diffraction pattern. Note whether the pattern is typical of chrysotile or amphibole, whether it is ambiguous, or neither chrysotile or amphibole. Energy dispersive X-ray analysis should be used where necessary to further characterize the fiber. Pictures representing the sample type, fiber/particulate distribution or characteristic SAED patterns of chrysotile and specific amphibole types may be taken as desired.

11. Count the fibers in grid openings until at least 100 fibers, or the fibers in a maximum of ten grid openings, have been counted. Once counting of fibers in a grid opening has started, the count shall be continued although the total count of fibers may be greater than 100.

12. To insure uniformity of grid opening dimensions, examine several 200 mesh grids by optical microscopy and measure roughly ten openings per grid. These dimensions are then averaged to provide a standard grid opening area.

13. Calculate the dilution factor as follows:

$$\text{Dilution Factor} = \frac{4 \times 100}{\text{size of aliquot used in step 6(ml)}}$$

The number 4 appears in the numerator because 1/4 of the original filter is used. The dilution factor will be 40, 20 or 5.71 corresponding to the 10,20 and 70 ml aliquots respectively.

14. Calculate the area factor as follows:

$$\text{Area Factor} = \frac{\text{Total effective filter area of the Nuclepore filter} (cm^2)}{\text{Area Examined } (cm^2)}$$

where Area Examined (cm^2) =

(average area of an EM grid opening (cm^2))
x (number of grid openings examined during fiber counting).

15. Filter density (number per m^3) and mass concentration (ng/m^3) are calculated using the following formula:

Number of Fibers/m^3 =

$$\frac{\text{Total Number of Fibers Counted x Area Factor x Dilution Factor}}{\text{Air Volume } (m^3)}$$

Mass Concentration (ng/m^3) =

$$\frac{\text{Total Fiber Volume } (\mu m^3) \text{ x Density } (ng/\mu m^3) \text{ x Area Factor x Dilution Factor}}{\text{Air Volume } (m^3)}$$

where

$$\text{Total Fiber Volume} = \sum_{i=1}^{\text{Number of Fibers}} \text{Length}_i\,(\mu m)\,(\text{WIDTH}_i\,(\mu m))^2 \left(\frac{\pi}{4}\right)$$

and Density equals 3.0×10^{-3} $ng/\mu m^3$ for amphibole and $2.6 \times 10^{-3} ng/\mu m^3$ for chrysotile. Length_i is the length of fiber i in μm and width_i is the width of fiber i in μm. (Note: It is often convenient to measure length in units of $\frac{\mu m}{4}$ and width in units of $\frac{\mu m}{20}$. When this is the case the formula becomes

$$\text{Total Fiber Volume} = \sum_{i=1}^{\text{Number of Fibers}} \frac{Li}{4}(\mu m) \left(\frac{Wi}{20}\ (\mu m)\right)^2 \frac{\pi}{4}$$

where Li is the length of fiber i in $\frac{\mu m}{4}$ and Wi = width of fiber i in $\frac{\mu m}{20}$.

APPENDIX B-6

PHASE CONTRAST MICROSCOPY PROTOCOL

Phase Contrast Microscopy is used to determine concentrations of fibers greater than 5 μm in length on filtered collections of air samples. No identification of the fiber type is made by this procedure. This is the standard NIOSH method described in the DHEW (NIOSH) publication, No. 790127, entitled "USPHS/NIOSH Membrane Filter Method for Evaluating Airborne Asbestos Fibers."

The phase contrast microscopy (PCM) method employs a phase microscope equipped with a Porton reticle to count fibers greater than 5.0 m (with an aspect ratio or ratio of length to diameter greater than 3:1) over specific areas of cleared membrane filters. A radial section from the membrane filter used to collect air particulate from a measured volume of air is made transparent by mounting the section in a clearing solution consisting of a 1:1 mixture of diethyl oxalate and dimethyl phthalate plus 0.05 g/ml of dissolved Millipore filter.

The cleared filter section is placed beneath a coverslip on a microscope slide and scanned along the radius of the filter. Fibers are counted within 100 fields as delineated by the Porton reticle. The area of one Porton reticle field is 1/333 mm^2. After calculating the effective area of the particular filter, the number of fibers per m^3 of air is calculated by the following formula:

$$\text{number of fibers/m}^3 = \frac{\text{Number of fibers counted} \times \text{filter area (mm}^2)}{100 \times (\text{area of one reticle field (mm}^2)) \times \text{volume of sampled air (m}^3))}$$

$$= \frac{\text{Number of fibers counted} \times \text{filter area (mm}^2) \times 333.}{100 \times (\text{volume of sampled air (m}^3))}$$

APPENDIX B-7

CONTRACTOR SPECIFICATIONS FOR REMOVAL

PART 1 - GENERAL

1.01 SCOPE

A. This specification covers the removal of acoustical plaster materials that have previously been determined to contain asbestos.

1.02 DESCRIPTION OF WORK

A. Remove asbestos-containing acoustical materials from ceilings and some walls in 20 buildings within the Public School System,

B. Furnish all labor, materials, services, insurance, equipment, in accordance with requirements of EPA and OSHA regulatory agencies, to complete removal as specified, of all asbestos-containing material located in the areas indicated on drawings enclosed.

1.03 TERMINOLOGY

A. Abatement - Procedures to decrease or eliminate fiber release from spray or asbestos-containing building materials. For purposes of this contract, abatement includes removal only.

B. Removal - the act of removing asbestos-containing or contaminated materials from the structure to a suitable disposal site.

C. Air Monitoring - the process of measuring the fiber content of a specific volume of air in a stated period of time.

D. HEPA Vacuum Equipment - High efficiency particulate absolute filtered vacuuming equipment with a filter system capable of collecting and retaining asbestos fibers. Filters should be of 99.97% efficiency for retaining fibers of 0.3 microns or larger.

E. Surfactant - A chemical wetting agent, added to water to improve penetration, thus reducing the quantity of water required for a given operation or area.

F. Amended water - Water to which a surfactant is added.

G. Airlock (Curtained doorway) - A device to allow ingress or egress from one room to another while permitting minimal air movement between the rooms, typically constructed by placing three overlapping sheets of plastic sheet over an existing or temporarily framed doorway and by securing each along the top of the doorway, the vertical edge attached on alternate sides of opening with arrows painted on each sheet to direct persons in the proper direction for entry and exit.

H. Decontamination Enclosure System - A series of connected rooms, with curtained doorways between any two adjacent rooms, for the decontamination of workers or of materials and equipment. A decontamination enclosure system always contains an airlock.

I. Worker Decontamination Enclosure System - A decontamination enclosure system for workers, typically consisting of a clean room, a shower room, and an equipment room.

J. Equipment Decontamination Enclosure System - A decontamination enclosure system for materials and equipment, typically consisting of a designated area of the work area, a washroom, and an uncontaminated area.

K. Clean Room - An uncontaminated area or room which is part of the worker decontamination enclosure system, with provisions for storage of workers' street clothes and protective equipment.

L. Shower Room - A room, constituting an airlock, between the clean room and the equipment room in the worker decontamination enclosure system, with hot and cold or warm running water suitably arranged for complete showering of workers during decontamination. The shower room always comprises an airlock.

M. Equipment Room - A contaminated area or room which is part of the worker decontamination enclosure system, with provisions for storage of contaminated clothing and equipment.

N. HEPA Filter - A High Efficiency Particulate Absolute (HEPA) filter capable of trapping and retaining 99.97% of asbestos fibers greater than 0.3 microns in size.

O. Wet Cleaning - The process of eliminating asbestos contamination from building surfaces and objects by using cloths, mops, or other cleaning tools which have been dampened with water, and by afterwards disposing of these cleaning tools as asbestos-contaminated waste.

1.04 APPLICABLE DOCUMENTS (REFERENCES)

A. The current issue of each document shall govern. Where conflict among requirements or with these specifications exist, the more stringent requirements shall apply.

B. Title 29, Code of Federal Regulations, Section 1910.1001 Occupational Safety and Health Administration (OSHA), U.S. Department of Labor.

C. Title 40, Code of Federal Regulations, Part 61, Subparts A and B, National Emission Standards for Hazardous Air Pollutants. U.S. Environmental Protection Agency (EPA).

D. Codes and Standards.

1. ASTM - American Society for Testing and Material.

2. ANSI - American National Standards Institute.

3. U.L.I. - Underwriters Laboratories, Inc.

4. Uniform Building Code

1.05 SUBMITTALS AND NOTICES

A. Prior to commencement of work, notify in writing the EPA Regional Office with jurisdiction over the State in which this project is located, not fewer than ten (10) days before work commences on this project.

B. Prior to commencement of work, file Notification for Removal and Disposal of Asbestos-Containing Materials in at least 20 days before commencement of project. Copies of notifications and an estimated quantity of waste and schedule of disposal shall be filed with the prior to the start of construction. The 20 day notice may be amended if contractor elects to start work by May 16, 1983.

C. Submit proof satisfactory to the building owner that all required permits, site location, and arrangements for transport and disposal of asbestos containing or contaminated materials, supplies, and the like have been obtained.

D. Submit to the building owner a description of the plans for construction of a decontamination area and for isolation of the work areas in compliance with this specification and applicable regulations.

E. Submit proof satisfactory to the building owner that all employees have had instruction on the hazards of asbestos exposure, on use and fitting of respirators, on protective dress, on use of showers, on entry and exit from work areas, and on all aspects of work procedures and protection measures.

F. Post the EPA and OSHA regulations concerning asbestos abatement procedures at the job site.

1.06 TEST RESULTS

A. Results of tests of asbestos-containing materials taken from surfaces within the scope of this project are available for inspection at the School District Office and at the Architect's office.

1.07 WORKER PROTECTION

A. Provide workers with personally issued and maked respiratory equipment suitable for the the asbestos exposure level in the work area according to ASHA Standard 29 CFR 1910.1001. Where respirators with disposable filters are employed, provide sufficient filters for replacement as necessary by the worker, or as required by the applicable regulation.

B. Provide authorized visitors with suitable respirators with fresh filters or cartridges whenever they are required to enter the work area, to maximum of 4 per day.

C. Provide workers with sufficient sets of disposable full body clothing. Such clothing shall consist of full body coveralls and headgear. Provide eye protection as required by applicable safety regulations. Non-disposable clothing and footwear shall be left in the Contaminated Equipment Room until the end of the asbestos abatement work, at which time such items shall be disposed of as asbestos waste, or shall be thoroughly cleaned of all asbestos or asbestos-containing material.

D. Provide authorized visitors with a set of suitable disposable clothing, headgear, eye protection and footwear, whenever they are required to enter the work area, to a maximum of 4 set(s) per day.

E. Provide and post, in the Equipment Room and the Clean Room, the decontamination and work procedures to be followed by workers, as follows:

1. Each worker and authorized visitor shall, upon entering the job site: remove street clothes in the clean change room and put on a respirator with new filters, and disposable clothing before entering the equipment and access areas or the work area.

2. Worker Decontamination. Each worker and authorized visitor shall, each time he leaves the work area: remove gross contamination from clothing before leaving the work area; proceed to the equipment area and remove all clothing except respirators; still wearing the resprirator proceed naked to the showers; clean the outside of the respirator with soap and water while showering; remove the respirator, thoroughly shampoo and wash themselves; remove filters and wet them and dispose of filters in the container provided for the purpose; and wash and rinse the inside of the respirator.

3. Following showering and drying off, each worker and authorized visitor shall proceed directly to the clean change room and dress in street clothes at the end of each day's work, or in clean coveralls before eating, smoking, drinking, or reentering the work area.

4. Contaminated work footwear shall be stored in the equipment room when not in use in the work area. Upon completion of asbestos abatement, dispose of footwear as contaminated waste or clean thoroughly inside and out using soap and water before removing from work area or from equipment and access area. Store contaminated worksuits in the equipment room for reuse or place in receptacles for disposal with other asbestos contaminated materials.

5. Workers removing waste containers from the equipment decontamination enclosure shall enter the washroom from outside wearing a respirator and dressed in clean coveralls. No worker shall use this system as a means to leave or enter the work area.

6. Workers shall not eat, drink, smoke, or chew gum or tobacco at the worksite except in the established clean room.

7. Workers shall be fully protected with respirators and protective clothing during preparation of system of enclosures prior to commencing actual asbestos abatement and until final clean-up is completed.

1.08 BUILDING PROTECTION

A. Provide temporary partitions to allow continued building occupancy by Owner.

B. Maintain free and safe passage to and from buildings for all occupants.

C. Be responsible for building security through areas controlled by the Contractor.

D. Protect building from damage caused by removal and transporting of material, water and showers, spraying of material to be removed and wet cleaning.

1.09 CONTRACTOR QUALIFICATIONS

A. Prior to award of Contract and upon request of Architect or Owner, the Contractor shall furnish proof of qualifications in the form of a list of similar projects successfully completed or proof of successful completion of training sessions or experience in asbestos abatement work.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Deliver all materials in the original packages, containers, or bundles bearing the name of the manufacturer and the brand name.

B. Store all materials subject to damage off the ground, away from wet or damp surfaces, and under cover sufficient to prevent damage or contamination.

C. Damaged or deteriorating materials shall not be used and shall be removed from the premises. Material that becomes contaminated with asbestos shall be disposed of in accordance with the applicable regulations.

D. Plastic sheet, of the thicknesses specified, in sizes to minimize the frequency of joints.

E. Tape - glass fiber or other type capable of sealing joints of adjacent sheets of plastic sheets and for attachment of plastic sheet to finished or unfinished surfaces of dissimilar materials under both dry and wet conditions, including use of amended water.

F. Surfactant (wetting agent) - shall consist of 50% polyoxyethylene ether and 50% of (polyoxyethylene) (Polyglycol) ester, or equivalent, and shall be mixed with water to provide a concentration of one ounce surfactant to 5 gallons of water.

G. Impermeable containers - suitable to receive and retain any asbestos-containing or contaminated materials until disposal at an approved site. The containers shall be labeled in accordance with OSHA Regulation 29 CFR 1910.1001 or EPA Regulation 40 CFR 61.22(j). Containers must be both air and water-tight. If plastic bags are used the plastic bags shall be 6 mil thick.

H. Warning labels and signs - as required by OSHA regulation 29 CFR 1910.1001.

I. Spray or Trowel Applied Acoustical Plaster and/or plaster - Asbestos-free material as specified elsewhere in this specification.

J. Other Materials - Provide all other materials, such as lumber, nails and hardware, which may be required to construct and dismantle the decontamination area and the barriers that isolate the work area.

2.02 TOOLS AND EQUIPMENT

A. Provide suitable tools for asbestos removal.

B. Water Sprayer - Airless or other low pressure sprayer for amended water application.

C. Air Purifying Equipment - High Efficiency Particulate Absolute Filtration Systems or Electronic Precipitators. No air movement system or air equipment shall discharge any asbestos fibers outside the work area.

D. Scaffolding - As required to accomplish the specified work shall meet all applicable safety regulations.

E. Transportation - As required, to be suitable for loading, temporary storage, transit, and unloading of contaminated waste without exposure to persons or property.

PART 3 - EXECUTION

A. Before commencing work in any area, Contractor accompanied by a representative of the Owner, shall inspect, note and tag all items scheduled for Contractor to remove and replace. Contractor shall inspect in all rooms in which work is to be performed. Contractor shall note any and all damaged or non-working items and tag with tags furnished by Owner's representative. All damaged or non-working items removed and replaced by Contractor without tags shall be deemed damaged by the Contractor and replaced at no cost to the Owner. Copies of all lists on damaged or non-working items will be supplied to the Owner and Architect.

B. Work Areas: Isolate the work area for the duration of the work by completely sealing off all openings and fixtures.

C. Isolate heating, cooling, ventilating air systems to prevent contamination and fiber dispersal to other areas of the structure. During the work, vents within the work area shall be sealed with tape and plastic sheeting.

D. Preclean immovable objects, such as casework, plant, and equipment, within the proposed work areas, using HEPA vacuum equipment and/or wet cleaning methods as appropriate, and enclose with 6 mil plastic sheeting sealed with tape.

E. Clean the proposed work areas using HEPA vacuum equipment or wet cleaning methods as appropriate. Do not use methods that raise dust, such as dry sweeping or vacuuming with equipment not equipped with HEPA filters.

F. Seal off all openings such as corridors, doorways, ducts, and any other penetrations of the work areas with plastic sheeting sealed with tape. Doorways and corridors which will not be used for passage during work must be sealed with barriers as described herein.

G. Cover floor and wall surfaces with plastic sheeting sealed with tape. Use a minimum of two layers of 6 mil plastic on floors. Cover floors first so that plastic extends at least 12 in. up on walls, then cover walls with a minimum 4 mil plastic sheeting (single 4 mil layer or two layer application of 2 mil sheeting) to the floor level, thus overlapping the floor material by a minimum of 12 in.

H. Build airlocks at all entrances to and exits from the work area.

I. After inspection and tagging (if necessary), remove, lower and/or seal in plastic, ceiling mounted objects, such as lights, other fixtures not previously sealed off, and other objects that interfere with asbestos removal, as directed by the building owner. After electrical current has been disconnected, use localized water spraying or HEPA vacuum equipment during fixture removal to reduce fiber dispersal.

J. Maintain emergency and fire exits from the work areas, or establish alternative exits satisfactory to the applicable fire officials.

K. Provide temporary power and lighting and ensure safe installation of temporary power sources and equipment.

L. Provide decontamination enclosure system at each site in areas as agreed upon by the Owner.

   1. Build suitable framing or use existing rooms connected with framed-in tunnels if necessary and line with plastic sealed with tape at all lap joints in the plastic for all enclosures and decontamination enclosure system rooms.

   2. In all cases access between contaminated and uncontaminated rooms or areas shall be through an airlock as described herein. In all cases, access between any two rooms within the decontamination enclosure shall be through a curtained doorway.

M. Provide ventilating equipment with HEPA filters to maintain negative pressure within the work areas in which asbestos-containing material is being removed. Ventilating equipment must be operated 24 hours per day, seven days per week from start of removal work until after final clean up of asbestos removal. Use smoke test at start and finish of each days work to verify that direction of air flow is from clean area into work area. Do not allow pressure to pull airlocks open or pull plastic covers from walls or opening covers.

3.02 WORK DECONTAMINATION ENCLOSURE SYSTEM

A. Construct a worker decontamination enclosure system outside of the work area consisting of three totally enclosed chambers as follows:

   1. An equipment room with two curtained doorways, one to the work area and one to the shower room. The equipment room shall be of sufficient size to accommodate at least one worker, allowing him enough room to remove his protective clothing and footwear, and well as a 6 mil disposal bag and container and any other equipment which the Contractor wishes to store when not in use. The equipment room shall conform to the requirements of applicable regulations.

2. A shower room with two curtained doorways, one to the equipment room and one to the clean room. The shower room should contain at least one shower with hot and cold or warm water. Careful attention shall be paid to the shower to insure against leaking of any kind. The Contractors shall supply soap at all times in the shower room. Discharge shower waste water directly into a drain. Do not allow waste water to discharge onto playgrounds or yard areas.

3. A clean room with one curtain doorway into the shower and one entrance or exit to non-contaminated areas of the building. The clean room shall provide sufficient space for storage of the workers street clothes, towels, and other non-contaminated items.

3.03 EQUIPMENT DECONTAMINATION ENCLOSURE SYSTEM

A. Provide or construct a material/equipment decontamination enclosure system (washroom) with two curtained doorways, one to the work area and one to an uncontaminate area. Gross removal of dust and debris from contaminated material, material containers, and equipment shall be accomplished prior to moving to the washroom.

3.04 SEPARATION OF WORK AREAS FROM OCCUPIED AREAS

A. Separate parts of the building required to remain in use from parts of the building that will undergo asbestos abatement and replacement by means of airtight barriers, constructed as follows:

1. Build suitable floor to ceiling wood or metal framing and apply 3/8" minimum thickness plywood on work side.

2. Cover plywood barrier with plastic sheet, sealed with tape as specified on work area side.

3.05 MAINTENANCE OF ENCLOSURE SYSTEMS

A. Ensure that barriers and plastic linings are effectively sealed and taped. Repair damaged barriers and remedy defects immediately upon discovery.

B. Visually inspect enclosures at the beginning of each work period.

C. Use smoke methods to test effectiveness of barriers when directed by Building Owner.

3.06 AIR MONITORING

A. The Owner shall employ and pay for an independent air monitoring Contractor to provide environmental air monitoring inside and outside of the work area and outside the buildings during the term of this contract. As a condition of final acceptance of the work by the Owner, two air samples within 48 hours after completion of all cleaning work, shall be taken. After test results from lab analysis has been received, indicating that asbestos has been removed and rooms or areas have been found to be in compliance with all guidelines of OSHA, EPA, and other State and Local Government Agencies, the equipment, electrical and mechanical fixtures can be reinstalled.

3.07 ASBESTOS REMOVAL

A. Spray asbestos-containing material with amended water, using spray equipment capable of providing a "mist" application to prevent release of airborne fibers. Saturate the material sufficiently to wet it to the substrate without causing excess dripping. Spray the asbestos material repeatedly during work process to maintain wet condition and to minimize asbestos fiber dispersion.

B. Remove the saturated asbestos-containing material in small sections. As it is removed pack the material in sealable plastic bags of 6 mil minimum thickness and place in labeled containers for transport. Material shall not be allowed to dry out.

C. Seal filled containers. Clean external surfaces thoroughly by wet sponging. Remove from immediate working area to washroom. Clean, and move to uncontaminated area. Ensure that workers do not enter from uncontaminated areas into the washroom and work area.

D. After completion of stripping work, all surfaces from which asbestos has been removed shall be wire brushed, wet sponged or cleaned with High-Pressure water to remove all visible material and fibers in pockets or crevices. During this work, the surfaces being cleaned shall be kept wet.

E. The Owner, at their option, will take samples and pay for testing of same, both during and after the work has been completed, to determine if all asbestos-containing materials are being removed.

3.08 CLEAN-UP

A. Remove visible accumulations of asbestos-material and debris. Wet clean all contaminated surfaces.

B. Remove the plastic sheets from walls and floors only. The windows, doors and HVAC vents shall remain sealed and any HEPA filtration negative air pressure systems, air filtration and decontamination enclosure systems shall remain in service.

C. Clean all surfaces in the work area and any other contaminated areas with water and/or with HEPA vacuum equipment. After cleaning the work area, wait 24 hours to allow for settlement of dust, and again wet clean or clean with HEPA vacuum equipment all surfaces in the work area again. After completion of the second cleaning operation, perform a complete visual inspection of the work area to ensure that the work area is dust free.

D. Sealed drums and all equipment used in the work shall be included in the clean-up and shall be removed from work areas, via the equipment decontamination enclosure system, at an appropriate time in the cleaning sequence.

E. If the building owner finds that the work area has not been decontaminated, the Contractor shall repeat the wet cleaning until the work area is in compliance, at the Contractor's expense.

F. When a final inspection determines that the area has been decontaminated, the decontamination enclosure systems shall be removed, the area thoroughly wet cleaned, and materials from the equipment room and shower disposed of as contaminated waste. The remaining barriers between contaminated and clean areas and all seals on openings into the work area and fixtures shall be removed and disposed of as contaminated waste. A final check shall be carried out to ensure that no dust or debris remains on surfaces as a result of dismantling operations.

G. As the work progresses, to prevent exceeding available storage capacity on site, remove sealed and labeled containers of contaminated waste and dispose of as contaminated waste.

3.09 RE-ESTABLISHMENT OF OBJECTS AND SYSTEMS

A. Install sprayed acoustical plaster or plaster to ceiling as specified in Sections 09215, 09216 and 09217.

B. Install acoustical tile ceilings as specified in Section 09510.

C. Repair any and all damage to existing floors, walls, ceilings, and other surfaces and equipment caused by the work or the installation of barricades, enclosures, separations, etc.

   1. The Owner will provide painting system numbers to the Contractor for matching purposes where painted surfaces require touch-up. Color system based on PPG, 12 colors.

D. When clean-up is complete:

   1. Re-establish objects moved to temporary locations in the course of the work, in their proper positions.

   2. Re-secure mounted objects removed in the course of the work in their former position.

E. Re-establish HVAC, mechanical, and electrical systems in proper working order. Install new filters and dispose of used filters as contaminated waste. Clean ducts between rehabilitated spaces and adjacent rooms. Replace or clean duct linings to remove all friable asbestos.

Observations Made by Field Crew

In all schools, containment consisted of three layers of polyethylene film covering the floor and walls with the ceiling exposed. The film was sealed with duct tape and attached to the ceiling-wall edge with duct tape.

Each containment area was equipped with a shower enclosed by multi-layered polyethylene flap doors. Instructions to the removal crew were to remove clothes on the abatement side, shower and dry and dress in the exterior side. Removed material was bagged and sealed in poly bags which were transferred through a flap door into a poly lined storage area. The truck crew then entered the storage area through an outside flap door and removed the bagged material which was loaded directly into the rental truck.

In School No. 1, tunnels were constructed to connect the individual rooms. The tunnels were made of 2 x 4 frames with an 8 ft ceiling covered on all sides with several layers of polyethylene.

In School Nos. 3 and 4, tunnels were not constructed. Instead, the hallways connecting the removal areas were lined in the same manner as the rooms.

In School No. 2, small tunnels were erected down the center of the hallways. The tunnels were constructed of U-shaped pieces of 1/2 in. electrical thin wall conduit which were covered with poly film. Small branch tunnels led from the main tunnel to each room.

In all schools, after the containment was completed, the installation was visually inspected by the architect and the county health department. After the containment structure was approved, the work crew wearing protective equipment wet and stripped the material. The removed material was dropped to the floor where it was swept into piles, bagged and transferred to the holding area. After stripping was completed, the first layer of polyethylene film was then removed, bagged, and transferred to the holding area and treated as asbestos material. The containment area was then visually inspected by the architect and county health department. If the area was not clean, the remaining film was washed down until it passed visual inspection. In some cases the decision was made to remove one additional layer of the poly film in the cleaning process. The remaining one or two layers of polyethylene film were left in place until the new ceiling had been sprayed on and the area cleaned up. The remaining film was then removed for the final clean up.

In School Nos. 1, 2, and 3 the friable material was removed by scraping. In School No. 4, it was necessary to break the hard ceiling material with a hammer and remove the ceiling all the way down to the metal lath. In School No. 4 it was impossible to obtain good wetting of the ceiling material.

APPENDIX C

Results of Sample Analysis

APPENDIX C-1

TEM RESULTS

ID		Period	School	Site	Type	Sampling Time	Type of Analysis	Lab ID	Amphibole #Fiber	Amphibole Fib/m³	Amphibole ng/m³	Chrysotile # Fiber	Chrysotile Fib/m³	Chrysotile ng/m³
M7	1	1	2	2	A	21	S	M-7	0	0	0	49	3.70E+05	2.60E+00
S14	2	1	4	1	A	21	S	S-14	0	0	0	3	3.00E+04	1.00E-01
DG9	3	3	3	6	A	21	S	DG-9	0	0	0	4	3.00E+04	1.00E-01
DG25	4	3	3	6	A	35	S	DG-25	0	0	0	11	1.50E+04	4.60E-01
S2	5	1	3	4	A	21	S	S-2	0	0	0	7	2.00E+04	3.00E-01
S16	6	1	4	2	A	21	S	S-16	1	9000	0.4	2	2.00E+04	1.00E-01
MG9	7	3	2	4	A	21	S	MG-9	0	0	0	24	1.80E+05	8.50E-01
DG20	8	3	4	2	A	35	S	DG20	0	0	0	4	5.00E+03	4.00E-02
FB15	9	3	4	2	A	21	S	FB15	0	0	0	23	5.80E+04	1.90E+00
S26	10	1	2	4	A	35	S	S26	0	0	0	2	3.00E+03	1.00E-02
MG2	11	3	3	1	A	21	S	MG2	0	0	0	56	1.30E+05	9.60E-01
M18	12	1	3	1	A	35	S	M18	0	0	0	17	2.90E+04	2.60E-01
S27	13	1	2	2	A	35	S	S27	0	0	0	8	1.00E+04	3.00E-01
S22	14	1	4	2	A	35	S	S22	0	0	0	5	7.00E+03	1.00E-01
S10	15	1	2	5	A	21	S	S10	0	0	0	1	2.00E+03	1.00E-01
DG4	16	3	3	3	A	21	S	DG4	0	0	0	1	2.00E+03	1.00E-02
DG33	17	3	2	6	A	35	S	DG33	0	0	0	5	7.00E+03	7.00E-01
M5	18	1	3	1	A	21	S	M5	0	0	0	15	3.20E+04	3.70E-01
MG25	19	3	3	3	A	35	S	MG25	0	0	0	8	1.00E+04	2.00E-01
M17	20	1	1	2	A	35	S	M17	0	0	0	7	1.00E+04	6.00E-02
S19	21	1	1	6	A	35	S	S19	0	0	0	4	6.00E+03	1.00E-01
MG20	22	3	4	1	A	21	S	MG20	0	0	0	116	6.33E+05	9.48E+00
S6	23	1	3	3	A	21	S	S6	0	0	0	8	1.00E+04	1.00E-01
S25	24	1	3	4	A	35	S	S25	0	0	0	4	6.00E+03	6.00E-02
F89	25	3	1	1	NA	21	S	F89	0	0	0	23	5.30E+04	3.40E-01
DG21	26	3	3	2	NA	35	S	DG21	0	0	0	5	8.00E+03	4.00E-02
MG22	27	3	4	3	O	35	S	MG22	0	0	0	12	1.70E+04	1.30E-01
F4	28	1	1	7	O	35	S	F4	0	0	0	18	2.90E+04	1.60E-01
DG15	29	3	2	2	A	21	S	DG15	0	0	0	33	6.50E+04	7.40E-01
S21	30	1	4	1	A	35	S	S21	0	0	0	34	3.20E+04	2.80E-01
S28	31	1	2	6	A	35	S	S28C	0	0	0	8	1.00E+04	1.00E+00
M3	32	1	3	2	NA	21	R	M3R	0	0	0	16	3.50E+04	3.20E-01
MG29	33	.	.	.		.	S	MG29C	0	0	0	1	2.00E+03	3.00E-02
DG17	34	3	2	6	A	21	R	DG17R	0	0	0	6	1.00E+04	1.00E-01
M22	35	1	2	5	A	35	R	M22R	0	0	0	30	4.50E+04	4.60E-01
F6	36	1	3	7	O	35	S	F6C	0	0	0	1	1.00E+03	5.00E-03
M20	37	1	3	5	NA	35	R	M20R	0	0	0	13	2.50E+04	2.60E-01
DG2	38	3	3	2	NA	21	S	DG2C	0	0	0	1	2.00E+03	1.00E-02
DG19	39	3	1	1	NA	35	R	DG19R	0	0	0	74	9.50E+04	8.60E-01
DG15	40	3	2	2	A	21	D	DG15-D	0	0	0	18	3.50E+04	2.10E-01
MG22	41	3	4	3	O	35	D	MG22-D	0	0	0	15	2.10E+04	1.60E-01
S22	42	1	4	2	A	35	R	S22R	0	0	0	50	7.00E+04	4.10E-01
M22	43	1	2	5	A	35	S	M22C	0	0	0	128	3.86E+05	2.08E+00
S18	44	1	1	2	A	21	S	S18C	0	0	0	17	5.40E+04	2.40E-01
DG23	45	3	3	5	NA	35	S	DG23	0	0	0	1	1.00E+03	1.00E-02
DG17	46	3	2	6	A	21	S	DG17C	0	0	0	11	2.10E+04	2.70E-01
F6	47	1	3	7	O	35	R	F6R	0	0	0	5	6.00E+03	4.00E-02
DG2	48	3	3	2	NA	21	R	DG2R	0	0	0	8	2.00E+04	1.00E-01
S28	49	1	2	6	A	35	R	S28R	0	0	0	120	2.28E+05	1.13E+00
MG9	50	3	2	4	A	21	R	MG9R	0	0	0	19	4.00E+04	2.10E-01
MG16	51	3	1	6	A	35	R	MG16R	0	0	0	8	1.00E+04	1.00E-01
S18	52	1	1	2	A	21	R	S18R	0	0	0	3	9.00E+03	6.00E-02
MG16	53	3	1	6	A	35	S	MG16C	0	0	0	8	1.00E+04	9.00E-02
DG19	54	3	1	1	NA	35	S	DG19C	0	0	0	19	2.50E+04	1.50E-01
MG31	55	3	2	5	A	35	S	MG31C	0	0	0	6	9.00E+03	1.00E-01
MG25	56	3	3	3	A	35	R	MG25R	0	0	0	14	2.60E+04	1.80E-01
S14	57	1	4	1	A	21	R	S14R	0	0	0	103	4.01E+05	2.72E+00
MG33	58	3	2	4	A	35	S	MG33	0	0	0	1	5.00E+03	2.00E-02
M13	59	1	1	1	NA	21	D	M13-D	0	0	0	9	2.00E+04	2.00E-01
DG21	60	3	3	2	NA	35	D	DG21-D	0	0	0	8	1.00E+04	8.00E-02
S21	61	1	4	1	A	35	D	S21-D	0	0	0	181	1.71E+05	1.11E+00
DG20	62	3	4	2	A	35	D	DG20-D	0	0	0	9	1.00E+04	6.00E-02

TEM RESULTS (Continued)

ID		Period	School	Site	Type	Sampling Time	Type of Analysis	Lab ID	Amphibole			Chrysotile		
									#Fiber	Fib/m³	ng/m³	# Fiber	Fib/m³	ng/m³
DG33	63	3	2	6	A	35	D	DG33-D	0	0	0	7	9 00E+03	4 00E-02
M23	64	1	2	1	NA	35	S	M23	0	0	0	15	1 80E+04	9.70E-02
S10	65	1	2	5	A	21	D	S10-D	0	0	0	0	0 00E+00	0.00E+00
M5	66	1	3	1	A	21	D	M5-D	0	0	0	3	6.00E+03	1.00E-01
M18	67	1	3	1	A	35	D	M18-D	0	0	0	29	5.00E+04	2.40E-01
F4	68	1	1	7	O	35	D	F4-D	0	0	0	24	3.90E+04	2.20E-01
M23	69	1	2	1	NA	35	D	M23-D	0	0	0	22	2.60E+04	1.30E-01
MG33	70	3	2	4	A	35	D	MG33-D	0	0	0	6	3.00E+04	2.00E-01
F5	71	1	4	3	O	35	S	F5	0	0	0	49	7.00E+04	5.90E-01
M1	72	1	3	5	NA	21	S	M1	0	0	0	8	2.00E+04	3.00E-01
M21	73	1	2	3	NA	35	S	M21	0	0	0	14	2.40E+04	8.30E-02
S25	74	1	3	4	A	35	D	S25-D	0	0	0	4	6.00E+03	3.00E-02
M3	75	1	3	2	NA	21	S	M3C	0	0	0	10	2.20E+04	8.50E-02
M20	76	1	3	5	NA	35	S	M20C	0	0	0	41	7.80E+04	5.30E-01
MG4	77	3	3	4	A	21	S	MG4	0	0	0	520	3.63E+07	1.81E+02
MG29	78	.	.	.		.	R	MG29R	0	0	0	48	8.30E+04	3.70E-01
MG31	79	3	2	5	A	35	R	MG31R	0	0	0	47	6.70E+04	2.90E-01
MG27	80	3	3	7	O	35	S	MG27	0	0	0	15	2.10E+04	1.00E-01
MG4	81	3	3	4	A	21	D	MG4-D	0	0	0	210	1.47E+07	8.93E+01
S24	82	1	3	6	A	35	S	S24	0	0	0	66	1.10E+05	7.60E-01
FB8	83	3	1	6	A	21	S	FB8	0	0	0	0	0.00E+00	0.00E+00
DG29	84	3	2	2	A	35	S	DG29	0	0	0	0	0.00E+00	0.00E+00
MG18	85	.	.	.		.	S	MG18	0	0	0	0	0.00E+00	0.00E+00
MG24	86	3	3	1	A	35	S	MG24	0	0	0	8	5.00E+04	2.00E-01
DG12	87	3	2	3	NA	21	S	DG12	0	0	0	14	2.80E+04	3.60E-01
DG12	88	3	2	3	NA	21	D	DG12-D	0	0	0	41	8.10E+04	5.20E-01
B1	89	2	3	2	NA	35	S	B-1	0	0	0	17	2.40E+04	1.90E-01
M13	90	1	1	1	NA	21	S	M13	0	0	0	3	7.00E+03	2.00E-02
G6	91	2	3	10	A	35	S	G-6	0	0	0	103	1.02E+07	6.32E+01
G7	92	2	3	9	A	35	S	G-7	0	0	0	120	1.61E+07	1.41E+02
G7	93	2	3	9	A	35	E	G-7E	0	0	0	1	3.00E+03	1.00E-02
G14	94	2	2	8	A	35	S	G-14	0	0	0	55	5.00E+05	4.50E+00
G15	95	2	2	10	A	35	S	G-15	0	0	0	200	9.92E+06	8.13E+01
B8	96	2	2	7	O	35	S	B-8	0	0	0	0	0.00E+00	0.00E+00
K7	97	2	3	5	NA	35	S	K-7	0	0	0	4	6.00E+03	8.00E-02
K12B	98	2	2	3	NA	35	S	K-12B	0	0	0	42	5.00E+04	3.40E-01
K15	99	2	2	9	A	35	S	K-15	0	0	0	120	4.14E+06	2.49E+01
G22	100	2	1	1	NA	35	S	G-22	0	0	0	0	0.00E+00	0.00E+00
K23	101	2	1	9	A	35	S	K-23	0	0	0	102	1.48E+06	1.04E+01
G22	102	2	1	1	NA	35	E	G-22E	0	0	0	1	2.00E+03	2.00E-02
G23	103	2	1	7	O	35	S	G-23	0	0	0	2	3.00E+03	2.00E-02
G25	104	2	4	3	O	35	S	G-25	0	0	0	0	0.00E+00	0.00E+00
B2	105	2	3	8	A	35	S	B-2	0	0	0	0	0.00E+00	0.00E+00
B9	106	2	3	7	O	35	S	B-9	0	0	0	8	1.00E+04	4.00E-01
K24	107	2	4	6	A	35	S	K-24	0	0	0	135	1.22E+07	1.39E+02
K13B	108	2	2	11	A	35	E	K-13B-E	0	0	0	0	0.00E+00	0.00E+00
K13B	109	2	2	11	A	35	S	K-13B	0	0	0	53	6.80E+04	5.40E-01
B1	110	2	3	2	NA	35	D	B1D	0	0	0	6	9.00E+03	4.00E-01
G22	111	2	1	1	NA	35	R	G22R	0	0	0	4	6.00E+03	5.00E-02
K14	112	2	2	1	NA	35	S	K-14	0	0	0	14	2.00E+04	3.40E-01
B9	113	2	3	7	O	35	D	B-9D	0	0	0	21	2.70E+04	1.80E-01
B2	114	2	3	8	A	35	R	B-2R	0	0	0	49	7.20E+04	8.30E-01
K14	115	2	2	1	NA	35	R	K-14R	0	0	0	10	1.40E+04	1.00E-01
D25	116	4	4	1	A	35	S	D-25	0	0	0	46	5.40E+04	3.20E-01
D23	117	4	1	6	A	35	S	D-23	0	0	0	20	2.80E+04	1.50E-01
D21	118	4	1	7	O	35	S	D-21	0	0	0	3	4.00E+03	8.00E-02
D24	119	4	4	3	O	35	S	D-24	0	0	0	14	1.70E+04	8.10E-02
D29	120	4	3	6	A	35	S	D-29	0	0	0	33	4.30E+04	2.10E-01
D32	121	4	2	7	O	35	S	D-32	0	0	0	13	1.70E+04	8.50E-02
K24	122	2	4	6	A	35	R	K-24R	0	0	0	186	1.68E+07	1.41E+02
K15	123	2	2	9	A	35	R	K-15R	0	0	0	102	3 51E+06	2.21E+01
D34	124	4	2	6	A	35	S	D-34	0	0	0	1	1.00E+03	8.00E-03

TEM RESULTS (Continued)

ID		Period	School	Site	Type	Sampling Time	Type of Analysis	Lab ID	Amphibole #Fiber	Amphibole Fib/m^3	Amphibole ng/m^3	Chrysotile # Fiber	Chrysotile Fib/m^3	Chrysotile ng/m^3
D36	125	4	2	4	A	35	S	D-36	0	0	0	2	3.00E+03	2.00E-02
L25	126	4	3	2	NA	35	S	L-25	0	0	0	6	1.00E+04	3.00E-01
D27	127	4	3	7	O	35	S	D-27	0	0	0	2	3.00E+03	1.00E-02
J13	128	4	2	3	NA	35	S	J-13	0	0	0	10	1.40E+04	8.50E-02
L23	129	4	3	1	A	35	S	L-23	0	0	0	22	3.10E+04	2.30E-01
L27	130	4	3	3	A	35	S	L-27	0	0	0	88	9.60E+05	5.80E+00
L25	131	4	3	2	NA	35	R	L-25R	0	0	0	11	1.80E+04	7.60E-02
L23	132	4	3	1	A	35	D	L-23D	0	0	0	6	9.00E+03	3.00E-01
D25	133	4	4	1	A	35	R	D-25R	0	0	0	7	8.00E+03	5.00E-02
J11	134	4	3	4	A	35	R	J-11R	0	0	0	5	6.00E+03	5.00E-02
F8	135	1	2	7	O	35	S	F-8	0	0	0	2	3.00E+03	9.00E-03
S23	136	1	3	3	A	35	S	S-23	0	0	0	104	1.75E+05	1.12E+00
S20	137	1	1	1	NA	35	S	S-20	0	0	0	62	3.20E+05	1.60E+00
D36	138	4	2	4	A	35	R	D-36R	0	0	0	5	7.00E+03	3.00E-02
L29	139	4	2	1	NA	35	S	L-29	0	0	0	10	1.30E+04	6.50E-02
L30	140	4	2	2	A	35	S	L-30	0	0	0	77	1.10E+05	9.30E-01
D21	141	4	1	7	O	35	R	D-21R	0	0	0	3	4.00E+03	2.00E-02
F2	142	1	4	3	O	21	S	F-2	0	0	0	5	2.00E+04	5.00E-02
L33	143	4	2	5	A	35	S	L-33	0	0	0	5	7.00E+03	3.00E-02
S12	144	1	2	3	NA	21	S	S-12	0	0	0	11	2.60E+04	1.30E-01
FB17	145	3	2	1	NA	21	S	FB-17	0	0	0	2	5.00E+03	1.00E-02
FB13	146	3	4	3	O	21	S	FB-13	0	0	0	5	1.00E+04	2.00E-01
MG12	147	3	2	5	A	21	S	MG-12	0	0	0	23	4.00E+04	1.80E-01
M19	148	1	3	2	NA	35	S	M-19	0	0	0	0	0.00E+00	0.00E+00
J8	149	4	1	2	A	35	S	J-8	0	0	0	6	3.00E+04	2.00E-01
L22	150	4	4	2	A	35	S	L-22	0	0	0	29	1.20E+05	6.00E-01
S4	151	1	3	6	A	21	S	S-4	0	0	0	2	4.00E+03	3.00E-02
S8	152	1	2	4	A	21	S	S-8	0	0	0	16	3.60E+04	1.50E-01
M9	153	1	2	1	NA	21	S	M-9	0	0	0	25	5.50E+04	2.00E-01
M15	154	1	1	6	A	21	S	M-15	0	0	0	21	4.50E+04	2.40E-01
G14	155	2	2	8	A	35	D	G-14D	0	0	0	39	3.50E+05	4.10E+00
G25	156	2	4	3	O	35	R	G-25R	0	0	0	11	9.90E+04	8.60E-01
K23	157	2	1	9	A	35	D	K-23D	0	0	0	152	2.20E+06	1.46E+01
K13B	158	2	2	11	A	35	D	K-13B-D	0	0	0	43	5.50E+04	5.50E-01
D24	159	4	4	3	O	35	D	D-24D	0	0	0	19	2.20E+04	1.40E-01
D23	160	4	1	6	A	35	D	D-23D	0	0	0	57	8.10E+04	4.70E-01
L29	161	4	2	1	NA	35	D	L-29D	0	0	0	6	8.00E+03	4.00E-02
L30	162	4	2	2	A	35	D	L-30D	0	0	0	18	2.60E+04	1.40E-01
DG7	163	3	3	5	NA	21	S	DG-7	0	0	0	2	2.00E+04	9.00E-02
J11	164	4	3	4	A	35	S	J-11	0	0	0	0	0.00E+00	0.00E+00
DG31	165	3	2	1	NA	35	S	DG-31	0	0	0	4	2.00E+04	9.00E-02
DG27	166	3	2	3	NA	35	S	DG-27	0	0	0	0	0.00E+00	0.00E+00
H	167	1	0	0	LB	0	S	H	0	0	0	0		.
G	168	1	0	0	LB	0	S	G	0	0	0	0		.
J	169	1	0	0	LB	0	S	J	0	0	0	1		
B7	170	2	3	7	FB	0	S	B-7	0	0	0	0		.
G19	171	2	2	1	FB	0	S	G-16	0	0	0	0		.
G16	172	2	1	9	FB	0	S	G-16	0	0	0	0	.	.
D8	173	4	3	7	FB	0	S	D-8	0	0	0	5		.
D2	174	4	1	2	FB	0	S	D-2	0	0	0	0		
J1	175	4	1	1	FB	0	S	J-1	0	0	0	2	.	.
M10	176	1	2	1	FB	0	S	M-10	0	0	0	7		.
M8	177	1	2	2	FB	0	S	M-8	0	0	0	21		.
FB10	178	3	1	1	FB	0	S	FB-10	0	0	0	1		.
F3	179	1	1	7	FB	0	S	F-3	0	0	0	0	.	.
MG14	180	3	2	7	FB	0	S	MG-14	0	0	0	18	.	.
S31	181	2	0	0	LB	0	S	S-31	0	0	0	6	.	.
S32	182	2	0	0	LB	0	S	S-32	0	0	0	13	.	
FB7	183	3	1	6	FB	0	S	FB-7	0	0	0	0	.	.
L20	184	4	1	1	NA	35	S	L-20	0	0	0	39	5.50E+04	2.40E-01
M11		1	2	6	A	21	S	M-11	0	0	0	2	2.00E+04	4.00E-02

APPENDIX C-2

PCM RESULTS

ID	Period (Per)	School (Sch)	Site (Site)	Site Type (Type)	Sampling Time / Analysis Type (Anal)	Fibers*	Air Vol.	Fiber Density
A	1	0	0	LB	0S	.		.
B	1	0	0	LB	0S	.		.
D	1	0	0	LB	0S	.	.	.
E	1	0	0	LB	0S	.	.	.
F	1	0	0	LB	0S	.	.	.
G	1	0	0	LB	0S	.		.
H	1	0	0	LB	0S	.		.
I	1	0	0	LB	0S	.	.	.
J	1	0	0	LB	0S	.	.	.
K	1	0	0	LB	0S	.	.	.
B1	2	3	2	NA	35S	0	10	0.00E+00
B1	2	3	2	NA	35D	2	10	6.00E+02
B2	2	3	8	A	35S	22	10	7.30E+03
B2	2	3	8	A	35R	2	10	7.00E+02
B3	2	2	7	O	21S	.	.	.
B4	2	2	7	FB	0S	.	.	.
B5	2	4	3	FB	0S	.	.	.
B6	2	3	7	O	21S	.	.	.
B7	2	3	7	FB	0S	.	.	.
B8	2	2	7	O	35S	10	9	3.60E+03
B8	2	2	7	O	35R	4	9	1.00E+03
B9	2	3	7	O	35S	6	11	2.00E+03
D1	4	1	7	FB	0S	.	.	.
D2	4	1	2	FB	0S	.	.	.
D3	4	1	2	A	21S	.	.	.
D4	4	4	3	FB	0S	.	.	.
D5	4	4	3	O	21S	.	.	.
D6	4	4	1	FB	0S	.	.	.
D7	4	4	1	A	21S	.	.	.
D8	4	3	7	FB	0S	.	.	.
F1	1	4	3	FB	0S	.	.	.
F2	1	4	3	O	21S	.	.	.
F3	1	1	7	FB	0S	.	.	.
F4	1	1	7	O	35S	1	9	4.00E+02
F4	1	1	7	O	35R	4	9	1.00E+03
F5	1	4	3	O	35S	7	10	2.00E+03
F6	1	3	7	O	35S	1	11	3.00E+02
F6	1	3	7	O	35R	1	11	3.00E+02
F7	1	3	7	FB	0S	.	.	.
F8	1	2	7	O	35S	2	10	7.00E+02
F8	1	2	7	O	35D	17	10	5.80E+03
F9	1	2	7	FB	0S	.	.	.
G1	2	3	2	FB	0S	.	.	.
G2	2	3	10	A	21S	.	.	.
G3	2	3	10	FB	0S	.	.	.
G4	2	3	2	NA	21S	.	.	.
G5	2	3	7	FB	0S	.	.	.
G6	2	3	10	A	35S	6	10	2.00E+03
G6	2	3	10	A	35D	1	10	3.00E+02
G7	2	3	9	A	35S	16	7	6.90E+03
G8	2	2	11	FB	0S	.	.	.
G9	2	2	11	A	21S	.	.	.
J1	4	1	1	FB	0S	.	.	.
J2	4	1	1	NA	21S	.	.	.
J3	4	3	4	FB	0S	.	.	.
J4	4	3	4	A	21S	.	.	.
J6	4	2	3	FB	0S	.	.	.
J7	4	2	3	NA	21S	.	.	.
J8	4	1	2	A	35S	1	11	3.00E+02
J8	4	1	2	A	35D	2	11	6.00E+02
K1	2	3	5	FB	0S	.	.	.
K2	2	3	5	NA	21S	.		

* "S" denotes standard.
"D" denotes duplicate.
"R" denotes replicate.

PCM RESULTS (Continued)

ID	Per	Sch	Site	Type	Anal	Fibers*	Air Vol.	Fiber Density
K3	2	3	8	FB	OS	.	.	.
K4	2	3	8	A	21S	.	.	
K5	2	3	9	A	21S	.	.	.
K6	2	3	9	FB	OS	.	.	.
K7	2	3	5	NA	35S	2	10	6.00E+02
K7	2	3	5	NA	35D	0	10	0.00E+00
K8	2	2	3	FB	OS	.	.	.
K9	2	2	3	NA	21S	.	.	
L2	4	1	6	A	21S	.	.	.
L3	4	1	6	FB	OS	.	.	.
L4	4	4	2	A	21S	.	.	.
L5	4	4	2	FB	OS	.	.	.
L6	4	3	1	A	21S	.	.	.
L7	4	3	1	FB	OS	.	.	.
L8	4	3	2	NA	21S	.	.	.
L9	4	3	2	FB	OS	.	.	.
M1	1	3	5	NA	21S	.	.	.
M2	1	3	5	FB	OS	.	.	.
M3	1	3	2	NA	21S	.	.	.
M4	1	3	2	FB	OS	.	.	.
M5	1	3	1	A	21S	.	.	.
M6	1	3	1	FB	OS	.	.	.
M7	1	2	2	A	21S	.	.	
M8	1	2	2	FB	OS	.	.	.
M9	1	2	1	NA	21S	.	.	.
S1	1	3	4	FB	OS	.	.	.
S2	1	3	4	A	21S	.		.
S3	1	3	6	FB	OS	.		.
S4	1	3	6	A	21S	.	.	.
S5	1	3	3	FB	OS	.	.	.
S6	1	3	3	A	21S	.	.	.
S7	1	2	4	FB	OS	.	.	.
S8	1	2	4	A	21S	.	.	.
S9	1	2	5	FB	OS	.	.	.
B10	2	3	7	FB	OS	.	.	.
B11	2	1	7	O	21S	.	.	.
B12	2	1	7	FB	OS	.	.	.
B13	2	4	3	O	21S	.	.	.
D10	4	3	6	FB	OS	.	.	.
D11	4	3	6	A	21S	.	.	.
D12	4	3	5	FB	OS	.	.	.
D13	4	3	5	NA	21S	.	.	.
D14	4	2	7	FB	OS	.	.	.
D16	4	2	4	FB	OS	.	.	.
D17	4	2	4	A	21S	.	.	.
D18	4	2	6	FB	OS	.	.	.
D19	4	2	6	A	21S	.	.	.
D21	4	1	7	O	35S	0	10	0.00E+00
D21	4	1	7	O	35D	3	10	1.00E+03
D23	4	1	6	A	35S	2	10	6.00E+02
D24	4	4	3	D	35S	0	12	0.00E+00
D25	4	4	1	A	35S	2	12	5.00E+02
D27	4	3	7	O	35S	3	10	1.00E+03
D27	4	3	7	O	35R	0	10	0.00E+00
D29	4	3	6	A	35S	1	11	3.00E+02
D29	4	3	6	A	35R	7	11	2.00E+03
D32	4	2	7	O	35S	0	11	0.00E+00
D34	4	2	6	A	35S	11	11	3.20E+03
D34	4	2	6	A	35R	6	11	2.00E+03
D36	4	2	4	A	35S	46	10	1.50E+04
DG1	3	3	2	FB	OS			
DG2	3	3	2	NA	21S			

PCM RESULTS (Continued)

ID	Per	Sch	Site	Type	Anal	Fibers*	Air Vol.	Fiber Density
DG3	3	3	3	FB	OS	.	.	.
DG4	3	3	3	A	21S	.	.	.
DG6	3	3	5	FB	OS	.	.	.
DG7	3	3	5	NA	21S	.	.	.
DG8	3	3	6	FB	OS	.	.	.
DG9	3	3	6	A	21S	.	.	.
FB1	3	0	0	LB	OS	.	.	.
FB2	3	0	0	LB	OS	.	.	.
FB4	3	1	7	FB	OS	.	.	.
FB5	3	1	7	O	21S	.	.	.
FB7	3	1	6	FB	OS	.	.	.
FB8	3	1	6	A	21S	.	.	.
FB9	3	1	1	NA	21S	.	.	.
G10	2	2	8	A	21S	.	.	.
G11	2	2	8	FB	OS	.	.	.
G12	2	2	10	A	21S	.	.	.
G13	2	2	10	FB	OS	.	.	.
G14	2	2	8	A	35S	5	11	1.00E+03
G14	2	2	8	A	35R	18	11	5.20E+03
G15	2	2	10	A	35S	20	10	6.40E+03
G16	2	1	9	FB	OS	.	.	
G17	2	1	10	FB	OS	.	.	.
G18	2	1	1	NA	21S	.	.	.
G19	2	1	1	FB	OS	.	.	.
G20	2	4	5	FB	OS	.	.	.
G21	2	4	5	A	21S	.	.	.
G22	2	1	1	NA	35S	0	10	0.00E+00
G22	2	1	1	NA	35R	0	10	0.00E+00
G23	2	1	7	O	35S	1	11	3.00E+02
G23	2	1	7	O	35R	5	11	1.00E+03
G25	2	4	3	O	35S	1	11	3.00E+02
G25	2	4	3	O	35D	0	11	0.00E+00
J11	4	3	4	A	35S	42	12	1.10E+04
J13	4	2	3	NA	35S	191	10	6.12E+04
J13	4	2	3	NA	35D	94	10	3.00E+04
K10	2	2	9	A	21S	.	.	.
K11	2	2	9	FB	OS	.	.	.
K14	2	2	1	NA	35S	0	10	0.00E+00
K15	2	2	9	A	35S	2	10	7.00E+02
K16	2	1	10	A	21S	.	.	.
K17	2	1	9	A	21S	.	.	.
K18	2	4	6	A	21S	.	.	.
K19	2	4	6	FB	OS	.	.	.
K20	2	4	4	FB	OS	.	.	.
K23	2	1	9	A	35S	23	10	7.50E+03
K24	2	4	6	A	35S	3	11	9.00E+02
K24	2	4	6	A	35D	7	11	2.00E+03
L10	4	3	3	FB	OS	.	.	.
L11	4	3	3	A	21S	.	.	.
L13	4	2	1	NA	21S	.	.	.
L14	4	2	1	FB	OS	.	.	.
L15	4	2	2	A	21S	.	.	.
L16	4	2	2	FB	OS	.	.	.
L18	4	2	5	A	21S	.	.	.
L19	4	2	5	FB	OS	.	.	.
L20	4	1	1	NA	35S	125	10	4.00E+04
L20	4	1	1	NA	35R	81	10	2.60E+04
L22	4	4	2	A	35S	210	12	5.61E+04
L22	4	4	2	A	35R	113	12	3.02E+04
L23	4	3	1	A	35S	66	10	2.10E+04
L25	4	3	2	NA	35S	155	9	5.84E+04
L25	4	3	2	NA	35R	47	9	1.80E+04

PCM RESULTS (Continued)

ID	Per	Sch	Site	Type	Anal	Fibers*	Air Vol.	Fiber Density
L27	4	3	3	A	35S	227	9	7.99E+04
L27	4	3	3	A	35D	150	9	5.28E+04
L29	4	2	1	NA	35S	322	11	9.38E+04
L30	4	2	2	A	35S	148	10	4.89E+04
L30	4	2	2	A	35R	103	10	3.40E+04
L33	4	2	5	A	35S	63	10	2.00E+04
L33	4	2	5	A	35D	60	10	1.90E+04
M10	1	2	1	FB	OS	.	.	.
M11	1	2	6	A	21S	.	.	.
M12	1	2	6	FB	OS	.	.	.
M13	1	1	1	NA	21S	.	.	.
M14	1	1	1	FB	OS	.	.	.
M15	1	1	6	A	21S	.	.	.
M16	1	1	6	FB	OS	.	.	.
M17	1	1	2	A	35S	28	8	1.10E+04
M17	1	1	2	A	35R	27	8	1.10E+04
M18	1	3	1	A	35S	33	8	1.30E+04
M19	1	3	2	NA	35S	67	10	2.20E+04
M20	1	3	5	NA	35S	91	8	3.90E+04
M20	1	3	5	NA	35D	95	8	4.10E+04
M21	1	2	3	NA	35S	25	8	9.80E+03
M21	1	2	3	NA	35R	34	8	1.30E+04
M22	1	2	5	A	35S	33	9	1.10E+04
M22	1	2	5	A	35D	40	9	1.40E+04
M23	1	2	1	NA	35S	33	12	8.80E+03
M23	1	2	1	NA	35R	37	12	9.90E+03
MG1	3	3	1	FB	OS	.	.	.
MG2	3	3	1	A	21S	.	.	.
MG4	3	3	4	A	21S	.	.	.
MG5	3	3	4	FB	OS	.	.	.
MG6	3	3	7	FB	OS	.	.	.
MG7	3	3	7	O	21S	.	.	.
MG9	3	2	4	A	21S	.	.	.
S10	1	2	5	A	21S	.	.	.
S11	1	2	3	FB	OS	.	.	.
S12	1	2	3	NA	21S	.	.	.
S13	1	4	1	FB	OS	.	.	.
S14	1	4	1	A	21S	.	.	.
S15	1	4	2	FB	OS	.	.	.
S16	1	4	2	A	21S	.	.	.
S17	1	1	2	FB	OS	.	.	.
S18	1	1	2	A	21S	.	.	.
S19	1	1	6	A	35S	59	9	2.10E+04
S19	1	1	6	A	35D	54	9	1.90E+04
S20	1	1	1	NA	35S	37	10	1.20E+04
S20	1	1	1	NA	35D	33	10	1.10E+04
S21	1	4	1	A	35S	183	15	3.91E+04
S21	1	4	1	A	35R	146	15	3.12E+04
S22	1	4	2	A	35S	50	10	1.60E+04
S22	1	4	2	A	35D	48	10	1.50E+04
S23	1	3	3	A	35S	130	11	3.79E+04
S24	1	3	6	A	35S	76	8	3.00E+04
S24	1	3	6	A	35R	81	8	3.20E+04
S25	1	3	4	A	35S	83	9	3.00E+04
S26	1	2	4	A	35S	37	11	1.10E+04
S27	1	2	2	A	35S	80	8	3.30E+04
S27	1	2	2	A	35R	55	8	2.30E+04
S28	1	2	6	A	35S	51	10	1.70E+04
S28	1	2	6	A	35D	47	10	1.50E+04
S29	2	0	0	LB	OS	.	.	.
S30	2	0	0	LB	OS	.	.	.
S31	2	0	0	LB	OS	.	.	.

PCM RESULTS (Continued)

ID	Per	Sch	Site	Type	Anal	Fibers*	Air Vol.	Fiber Density
S32	2	0	0	LB	OS	.	.	.
DG11	3	2	3	FB	OS	.	.	.
DG12	3	2	3	NA	21S	.	.	
DG14	3	2	2	FB	OS	.	.	.
DG15	3	2	2	A	21S	.	.	.
DG16	3	2	6	FB	OS	.	.	
DG17	3	2	6	A	21S	.	.	.
DG19	3	1	1	NA	35S	40	11	1.20E+04
DG19	3	1	1	NA	35R	25	11	7.30E+03
DG20	3	4	2	A	35S	13	11	3.80E+03
DG21	3	3	2	NA	35S	11	9	4.10E+03
DG21	3	3	2	NA	35D	11	9	4.10E+03
DG23	3	3	5	NA	35S	3	10	1.00E+03
DG23	3	3	5	NA	35R	13	10	4.30E+03
DG25	3	3	6	A	35S	11	11	3.30E+03
DG25	3	3	6	A	35D	0	11	0.00E+00
DG27	3	2	3	NA	35S	.	.	.
DG29	3	2	2	A	35S	11	10	3.50E+03
DG29	3	2	2	A	35R	6	10	2.00E+03
DG31	3	2	1	NA	35S	4	10	1.00E+03
DG31	3	2	1	NA	35D	7	10	2.00E+03
DG33	3	2	6	A	35S	14	11	4.20E+03
FB10	3	1	1	FB	OS	.	.	.
FB12	3	4	3	FB	OS	.	.	.
FB13	3	4	3	O	21S	.	.	.
FB14	3	4	2	FB	OS	.	.	.
FB15	3	4	2	A	21S	.	.	.
FB16	3	2	1	FB	OS	.	.	.
FB17	3	2	1	NA	21S	.	.	.
K12A	2	2	1	NA	21S	.	.	.
K12B	2	2	3	NA	35S	4	12	1.00E+03
K12B	2	2	3	NA	35R	6	12	2.00E+03
K13A	2	2	1	FB	OS	.	.	.
K13B	2	2	11	A	35S	12	11	3.50E+03
K13B	2	2	11	A	35R	5	11	1.00E+03
MG10	3	2	4	FB	OS	.	.	.
MG11	3	2	5	FB	OS	.	.	.
MG12	3	2	5	A	21S	.	.	.
MG13	3	2	7	O	21S	.	.	.
MG14	3	2	7	FB	OS	.	.	.
MG16	3	1	6	A	35S	15	10	4.80E+03
MG16	3	1	6	A	35D	26	10	8.30E+03
MG20	3	4	1	A	21S	.	.	.
MG21	3	4	1	FB	OS	.	.	.
MG22	3	4	3	O	35S	6	10	2.00E+03
MG24	3	3	1	A	35S	28	11	8.20E+03
MG25	3	3	3	A	35S	9	8	4.00E+03
MG25	3	3	3	A	35R	10	8	4.20E+03
MG27	3	3	7	O	35S	9	10	3.00E+03
MG27	3	3	7	O	35D	26	10	8.30E+03
MG31	3	2	5	A	35S	9	10	3.00E+03
MG31	3	2	5	A	35D	36	10	1.20E+04
MG33	3	2	4	A	35S	11	10	3.50E+03

APPENDIX C-3

Results of Polarized Light Microscopic Analysis of Bulk Samples for Volume of Chrysotile and Nonasbestos Material and the Releasability Determination

Sample no.	Chrysotile volume %	Nonasbestos components volume %					R.R.[a]
		Mineral wool	Cellulose	Perlite	Vermiculite	Other	
F-11	85	T[b]	-	-	-	15	7
F-12	85	T	-	-	-	15	6
F-13	80	T	-	-	-	20	8
F-13[c]	25	10	5	-	-	60	5
F-14[d]	85	T	-	-	-	15	7
F-18	80	-	-	-	-	20	3
F-19	85	-	-	-	-	15	4
F-23[d]	85	-	-	-	-	15	5
F-24	25	-	-	10	60	5	5
F-24[c]	15	-	T	10	60	15	4
F-26	23	-	-	10	61	6	5
F-27	25	-	-	10	61	4	5
F-32[e]	15	-	-	-	50	35	4
F-34	27	-	-	-	67	6	4
F-36	25	-	-	-	70	5	4
F-38	25	-	-	65	-	10	5
F-38[c]	10	-	T	70	-	20	4
F-39	25	-	-	65	-	10	5
F-40[e]	3	-	-	-	-	97	3
F-41	30	-	-	60	-	10	5
F-47[e]	3	-	T	-	-	97	3
F-48	20	-	-	70	-	10	5
F-48[c]	15	-	T	45	-	40	5
F-49	20	-	-	70	-	10	5
F-50	20	-	-	70	-	10	5
F-53	20	-	-	70	-	10	5
F-58	20	-	-	70	-	10	5
F-59[d]	20	-	-	70	-	10	5
F-60	20	-	-	70	-	10	5
F-61	20	-	-	70	-	10	6
F-63	20	-	-	70	-	10	6
F-64[d]	20	-	-	70	-	10	5
F-66	20	-	T	70	-	10	5
M-24	25	-	-	10	60	5	6
M-28	25	-	-	10	59	6	6
M-30	25	-	-	9	60	6	5
M-31	25	-	-	10	60	5	6
M-31[c]	25	-	1	10	49	15	5
M-33	25	-	-	10	60	5	6
M-35[d]	25	-	-	10	60	5	6
M-37[e]	15	-	-	-	60	25	3
M-39	25	-	-	10	60	5	6

Sample no.	Chrysotile volume %	Nonasbestos components volume % Mineral wool	Cellulose	Perlite	Vermiculite	Other	R.R.[a]
M-39[c]	15	-	-	10	60	15	5
M-41	25	-	-	10	60	5	6
M-42	30	-	-	9	57	4	6
M-43[d]	25	-	-	12	56	7	6
M-45	25	-	-	12	56	7	5
M-49	30	-	-	10	54	6	5
M-50	30	-	-	10	54	6	6
M-52[e]	15	-	-	-	55	30	3
M-54	25	-	-	10	58	7	6
M-56	25	-	-	10	59	6	6
M-57[e]	15	-	-	-	55	30	3
M-58	25	-	-	10	59	6	5
M-59	25	-	-	10	58	7	5
M-65	85	T	-	-	-	15	5
M-67	25	-	-	-	70	5	3
M-68[e]	17	-	-	-	50	30	3
M-69	30	-	-	-	65	-	4
M-70	30	-	-	-	66	4	4
M-70[c]	25	-	-	-	65	10	4
M-74[d]	25	-	-	10	60	5	6
M-78	25	-	-	10	60	5	6
M-79	25	-	-	10	60	5	6
M-80	25	-	-	10	61	4	6
M-81[e]	15	-	-	-	50	35	3
M-83	25	-	-	-	72	3	4

[a]Releasability rating.
[b]T = trace amount.
[c]Internal duplicate QC analysis by MRI.
[d]Replicate analysis by MRI
[e]External QA laboratory

APPENDIX C-4

DATA USED FOR TEM QUALITY ASSURANCE

		TEM-CHRYS-STANDARD	TEM-CHRYS-DUPLICATE
		FIBER-COUNTS	FIBER-COUNTS
LENGTH	FILTER ID		
3-DAY SAMPLE	DG12	14	11
	DG15	33	18
	MG4	520	210
	M13	3	9
	M5	15	3
	S10	1	0
5-DAY SAMPLE	B1	17	6
	B9	8	21
	DG20	4	9
	DG21	5	8
	DG33	5	7
	D23	20	57
	D24	14	19
	F4	18	24
	G14	55	39
	K13B	53	43
	K23	102	152
	L23	22	6
	L29	10	6
	L30	77	18
	MG22	12	15
	MG33	1	6
	M18	17	29
	M23	15	22
	S21	34	181
	S25	4	4

LENGTH	FILTER ID	TEM-CHRYS-STANDARD FIBER-COUNTS	TEM-CHRYS-REPLICATE FIBER-COUNTS
3-DAY SAMPLE	DG17	11	6
	DG2	1	8
	MG9	24	19
	M3	10	16
	S14	3	103
	S18	17	3
5-DAY SAMPLE	B2	0	49
	DG19	19	74
	D21	3	3
	D25	46	7
	D36	2	5
	F6	1	5
	G22	0	4
	G25	0	11
	J11	0	5
	K14	14	10
	K15	120	102
	K24	135	186
	L25	6	11
	MG16	8	8
	MG25	8	14
	MG31	6	47
	M20	41	13
	M22	128	30
	S22	5	50
	S28	8	120

LENGTH	FILTER ID	TEM-CHRYS-STANDARD FIBER-COUNTS	TEM-CHRYS-EXTERNAL QA FIBER-COUNTS
3-DAY SAMPLE	DG9	4	95
	FB8	0	22
	FB9	23	95
	MG20	116	95
	M1	8	8
	M7	49	62
	S16	2	96
	S6	8	67
5-DAY SAMPLE	B1	17	95
	B8	0	34
	DG23	1	48
	DG25	11	98
	DG29	0	35
	D29	33	59
	D32	13	35
	F5	49	66
	G15	200	69
	G6	103	50
	G7	120	66
	L20	39	86
	L27	88	67
	L33	5	40
	MG24	8	48
	MG27	15	24
	M21	14	67
	S19	4	82
	S24	66	111
	S26	2	45

LENGTH	FILTER ID	TEM-CHRYS-STANDARD FIBERS - PER M**3	TEM-CHRYS-DUPLICATE FIBERS - PER M**3
3-DAY SAMPLE	DG12	28000	81000
	DG15	65000	35000
	MG4	36300000	14700000
	M13	7000	20000
	M5	32000	6000
	S10	2000	0
5-DAY SAMPLE	B1	24000	9000
	B9	10000	27000
	DG20	5000	10000
	DG21	8000	10000
	DG33	7000	9000
	D23	28000	81000
	D24	17000	22000
	F4	29000	39000
	G14	500000	350000
	K13B	68000	55000
	K23	1480000	2200000
	L23	31000	9000
	L29	13000	8000
	L30	110000	26000
	MG22	17000	21000
	MG33	5000	30000
	M18	29000	50000
	M23	18000	26000
	S21	32000	171000
	S25	6000	6000

LENGTH	FILTER ID	TEM-CHRYS-STANDARD FIBERS - PER M**3	TEM-CHRYS-REPLICATE FIBERS - PER M**3
3-DAY SAMPLE	DG17	21000	10000
	DG2	2000	20000
	MG9	180000	40000
	M3	22000	35000
	S14	30000	401000
	S18	54000	9000
5-DAY SAMPLE	B2	0	72000
	DG19	25000	95000
	D21	4000	4000
	D25	54000	8000
	D36	3000	7000
	F6	1000	6000
	G22	0	6000
	G25	0	99000
	J11	0	6000
	K14	20000	14000
	K15	4140000	3510000
	K24	12200000	16800000
	L25	10000	18000
	MG16	10000	10000
	MG25	10000	26000
	MG31	9000	67000
	M20	78000	25000
	M22	386000	45000
	S22	7000	70000
	S28	10000	226000

LENGTH	FILTER ID	TEM-CHRYS-STANDARD FIBERS - PER M**3	TEM-CHRYS-EXTERNAL QA FIBERS - PER M**3
3-DAY SAMPLE	DG9	30000	350000
	FB8	0	32000
	FB9	53000	2600000
	MG20	633000	7700000
	M1	20000	10000
	M7	370000	420000
	S16	20000	5900000
	S6	10000	2300000
5-DAY SAMPLE	B1	24000	240000
	B8	0	47000
	DG23	1000	65000
	DG25	15000	3100000
	DG29	0	57000
	D29	43000	760000
	D32	17000	630000
	F5	70000	200000
	G15	9920000	16000000
	G6	10200000	10000000
	G7	16100000	31000000
	L20	55000	3200000
	L27	960000	20000000
	L33	7000	47000
	MG24	50000	4200000
	MG27	21000	34000
	M21	24000	160000
	S19	6000	1900000
	S24	110000	921000
	S26	3000	57000

LENGTH	FILTER ID	TEM-CHRYS-STANDARD NG/M**3	TEM-CHRYS-DUPLICATE NG/M**3
3-DAY SAMPLE	DG12	0.36	0.32
	DG15	0.74	0.21
	MG4	181.00	89.30
	M13	0.02	0.20
	M5	0.37	0.10
	S10	0.10	0.00
5-DAY SAMPLE	B1	0.19	0.40
	B9	0.40	0.19
	DG20	0.04	0.06
	DG21	0.04	0.08
	DG33	0.70	0.04
	D23	0.15	0.47
	D24	0.08	0.14
	F4	0.16	0.22
	G14	4.50	4.10
	K13B	0.54	0.55
	K23	10.40	14.60
	L23	0.23	0.30
	L29	0.06	0.04
	L30	0.93	0.14
	MG22	0.13	0.16
	MG33	0.02	0.20
	M18	0.26	0.24
	M23	0.10	0.13
	S21	0.28	1.11
	S25	0.06	0.03

LENGTH	FILTER ID	TEM-CHRYS-STANDARD NG/M**3	TEM-CHRYS-REPLICATE NG/M**3
3-DAY SAMPLE	DG17	0.27	0.10
	DG2	0.01	0.10
	MG9	0.85	0.21
	M3	0.08	0.32
	S14	0.10	2.72
	S18	0.24	0.06
5-DAY SAMPLE	B2	0.00	0.83
	DG19	0.15	0.86
	D21	0.08	0.02
	D25	0.32	0.05
	D36	0.02	0.03
	F6	0.00	0.04
	G22	0.00	0.05
	G25	0.00	0.86
	J11	0.00	0.05
	K14	0.34	0.10
	K15	24.90	22.10
	K24	139.00	141.00
	L25	0.30	0.08
	MG16	0.09	0.10
	MG25	0.20	0.18
	MG31	0.10	0.29
	M20	0.53	0.26
	M22	2.09	0.46
	S22	0.10	0.41
	S28	1.00	1.13

LENGTH	FILTER ID	TEM-CHRYS-STANDARD NG/M**3	TEM-CHRYS-EXTERNAL QA NG/M**3
3-DAY SAMPLE	DG9	0.10	2.70
	FB8	0.00	0.39
	FB9	0.34	15.00
	MG20	9.48	45.00
	M1	0.30	0.10
	M7	2.60	2.00
	S16	0.10	39.00
	S6	0.10	26.00
5-DAY SAMPLE	B1	0.19	160.00
	B8	0.00	0.68
	DG23	0.01	4.30
	DG25	0.46	36.00
	DG29	0.00	0.43
	D29	0.21	6.20
	D32	0.08	5.40
	F5	0.59	1.20
	G15	81.30	19.00
	G6	63.20	160.00
	G7	141.00	360.00
	L20	0.24	24.00
	L27	5.80	140.00
	L33	0.03	0.32
	MG24	0.20	26.00
	MG27	0.10	0.34
	M21	0.08	0.93
	S19	0.10	24.00
	S24	0.76	10.70
	S26	0.01	0.43

TYPE	SAMPLE NO.	TEM-CHRYS-FIBER-COUNTS BLANK-ANALYSIS	TEM-CHRYS-FIBERS-PER FILTER BLANK-ANALYSIS	TEM-CHRYS-NG/FILTER BLANK-ANALYSIS
FIELD BLANKS	B7	0	0	0.00
	D2	0	0	0.00
	D8	5	70000	0.30
	FB10	1	50000	0.10
	FB7	0	0	0.00
	F3	0	0	0.00
	G16	0	0	0.00
	G19	0	0	0.00
	J1	2	30000	0.20
	MG14	18	260000	0.91
	M10	7	100000	0.40
	M8	21	300000	1.20
LABORATORY BLANKS	G	0	0	0.00
	H	0	0	0.00
	J	1	20000	0.10
	S31	6	90000	0.30
	S32	13	180000	0.70

APPENDIX C-5

DATA USED FOR PCM QUALITY ASSURANCE

FILTER ID	PCM-CHRYS-STANDARD FIBER-COUNTS	PCM-CHRYS-DUPLICATE FIBER-COUNTS
B1	0	2
DG21	11	11
DG25	11	0
DG31	4	7
D21	0	3
F8	2	17
G25	1	0
G6	6	1
J13	191	94
J8	1	2
K24	3	7
K7	2	0
L27	227	150
L33	63	60
MG16	15	26
MG27	9	26
MG31	9	36
M20	91	95
M22	33	40
S19	59	54
S20	37	33
S22	50	48
S28	51	47

FILTER ID	PCM-CHRYS-STANDARD FIBER-COUNTS	PCM-CHRYS-REPLICATE FIBER-COUNTS
B2	22	2
B8	10	4
DG19	40	25
DG23	3	13
DG29	11	6
D27	3	0
D29	1	7
D34	11	8
F4	1	4
F6	1	1
G14	5	18
G22	0	0
G23	1	5
K12B	4	6
K13B	12	5
L20	125	81
L22	210	113
L25	155	47
L30	148	103
MG25	9	10
M17	28	27
M21	25	34
M23	33	37
S21	183	146
S24	76	81
S27	80	55

FILTER ID	PCM-CHRYS-STANDARD FIBER-COUNTS	PCM-CHRYS-EXTERNAL QA FIBER-COUNTS
B9	6	1
DG20	13	15
DG27	.	5
DG33	14	8
D23	2	48
D24	0	0
D25	2	89
D32	0	1
D36	46	101
F5	7	3
G14	5	9
G22	0	3
G23	1	2
G7	16	19
J11	42	88
K14	0	3
K15	2	40
K23	23	14
L22	210	102
L23	66	48
L29	322	102
MG22	6	7
MG24	28	18
MG33	11	6
M18	33	32
M19	67	50
S23	130	102
S25	83	40
S26	37	41

FILTER ID	PCM-CHRYS-STANDARD FIBERS - PER M**3	PCM-CHRYS-DUPLICATE FIBERS - PER M**3
B1	0	600
DG21	4100	4100
DG25	3300	0
DG31	1000	2000
D21	0	1000
F8	700	5600
G25	300	0
G6	2000	300
J13	61200	30000
J8	300	600
K24	900	2000
K7	600	0
L27	79900	52800
L33	20000	19000
MG16	4800	8300
MG27	3000	8300
MG31	3000	12000
M20	39000	41000
M22	11000	14000
S19	21000	19000
S20	12000	11000
S22	16000	15000
S28	17000	15000

	PCM-CHRYS-STANDARD	PCM-CHRYS-REPLICATE
	FIBERS - PER M**3	FIBERS - PER M**3
FILTER ID		
B2	7300	700
B8	3600	1000
DG19	12000	7300
DG23	1000	4300
DG29	3500	2000
D27	1000	0
D29	300	2000
D34	3200	2000
F4	400	1000
F6	300	300
G14	1000	5200
G22	0	0
G23	300	1000
K12B	1000	2000
K13B	3500	1000
L20	40000	26000
L22	56100	30200
L25	58400	18000
L30	48900	34000
MG25	4000	4200
M17	11000	11000
M21	9800	13000
M23	8800	9900
S21	39100	31200
S24	30000	32000
S27	33000	23000

FILTER ID	PCM-CHRYS-STANDARD: FIBERS - PER M**3	PCM-CHRYS-EXTERNAL QA: FIBERS - PER M**3
B9	2000	300
DG20	3800	4500
DG27	.	2000
DG33	4200	2000
D23	600	16000
D24	0	0
D25	500	24000
D32	0	300
D36	15000	33100
F5	2000	1000
G14	1000	3000
G22	0	1000
G23	300	600
G7	6900	8300
J11	11000	24000
K14	0	800
K15	700	14000
K23	7500	4500
L22	56100	49800
L23	21000	16000
L29	93800	51600
MG22	2000	2000
MG24	8200	5400
MG33	3500	2000
M18	13000	13000
M19	22000	16000
S23	37900	40100
S25	30000	15000
S26	11000	12000

APPENDIX C-6

DATA USED FOR SEM QUALITY ASSURANCE

FILTER ID	SEM-CHRYS- STANDARD FIBER- COUNTS-AT 2000X	SEM-CHRYS- DUPLICATE FIBER- COUNTS-AT 2000X
DG22	0	0
DG30	0	0
DG32	0	0
D26	0	0
J12	0	0
J9	0	0
L28	0	0
MG17	0	0
MG26	0	0
RTI14	0	0
RTI15	0	0
RTI16	1	0
RTI17	0	0
RTI20	1	0
RTI21	2	1
RTI33	0	0
RTI39	2	0
RTI42	3	0
RTI7	0	0

	SEM-CHRYS-STANDARD	SEM-CHRYS-REPLICATE
	FIBER-COUNTS-AT 2000X	FIBER-COUNTS-AT 2000X
FILTER ID		
DG28	0	0
DG32	0	0
D28	0	0
D30	0	0
D33	0	0
J9	0	0
L31	0	0
L32	0	0
MG17	0	0
MG23	1	0
MG28	0	0
MG34	0	0
RTI1	0	0
RTI17	0	0
RTI18	0	0
RTI26	14	1
RTI27	7	3
RTI32	3	1
RTI34	0	1
RTI36	3	6
RTI4	0	0
RTI5	0	0
RTI8	0	0

FILTER ID	SEM-CHRYS-STANDARD FIBERS - PER M**3	SEM-CHRYS-DUPLICATE FIBERS - PER M**3
DG22	0	0
DG30	0	0
DG32	0	0
D26	0	0
J12	0	0
J9	0	0
L28	0	0
MG17	0	0
MG26	0	0
RTI14	0	0
RTI15	0	0
RTI16	700	0
RTI17	0	0
RTI20	800	0
RTI21	2000	700
RTI33	0	0
RTI39	1000	0
RTI42	2000	0
RTI7	0	0

	SEM-CHRYS-STANDARD	SEM-CHRYS-REPLICATE
	FIBERS - PER M**3	FIBERS - PER M**3
FILTER ID		
DG28	0	0
DG32	0	0
D28	0	0
D30	0	0
D33	0	0
J9	0	0
L31	0	0
L32	0	0
MG17	0	0
MG23	700	0
MG28	0	0
MG34	0	0
RTI1	0	0
RTI17	0	0
RTI18	0	0
RTI26	11000	800
RTI27	7000	4000
RTI32	3000	2000
RTI34	0	600
RTI36	2000	6000
RTI4	0	0
RTI5	0	0
RTI8	0	0

FILTER ID	SEM-CHRYS-STANDARD NG/M**3	SEM-CHRYS-DUPLICATE NG/M**3
DG22	0.00	0.00
DG30	0.00	0.00
DG32	0.00	0.00
D26	0.00	0.00
J12	0.00	0.00
J9	0.00	0.00
L28	0.00	0.00
MG17	0.00	0.00
MG26	0.00	0.00
RTI14	0.00	0.00
RTI15	0.00	0.00
RTI16	70.00	0.00
RTI17	0.00	0.00
RTI20	2000.00	0.00
RTI21	300.00	300.00
RTI33	0.00	0.00
RTI39	4.00	0.00
RTI42	200.00	0.00
RTI7	0.00	0.00

FILTER ID	SEM-CHRYS-STANDARD NG/M**3	SEM-CHRYS-REPLICATE NG/M**3
DG28	0.00	0.00
DG32	0.00	0.00
D28	0.00	0.00
D30	0.00	0.00
D33	0.00	0.00
J9	0.00	0.00
L31	0.00	0.00
L32	0.00	0.00
MG17	0.00	0.00
MG23	1.00	0.00
MG28	0.00	0.00
MG34	0.00	0.00
RTI1	0.00	0.00
RTI17	0.00	0.00
RTI18	0.00	0.00
RTI26	380.00	2.00
RTI27	800.00	30.00
RTI32	6.00	0.40
RTI34	0.00	5.00
RTI36	50.00	20.00
RTI4	0.00	0.00
RTI5	0.00	0.00
RTI8	0.00	0.00

TYPE	SAMPLE NO.	SEM-CHRYS-FIBER-COUNTS AT 2000X BLANK-ANALYSIS
FIELD BLANKS	DG10	0
	DG13	0
	D15	0
	D9	0
	FB6	0
	L1	0
	L12	0
	L17	0
	MG15	0
	RTI12	0
	RTI43	0
LABORATORY BLANKS	FB2	0
	RTI22	0

APPENDIX C-7

DATA USED FOR PLM ANALYSIS OF BULK SAMPLES FOR QUALITY ASSURANCE

	CHRYSOTILE-VOLUME %-STANDARD	CHRYSOTILE-VOLUME %-DUPLICATE	RELEASABILITY RATING-STANDARD	RELEASABILITY RATING-DUPLICATE
	DATA	DATA	DATA	DATA
SAMPLE NO.				
F-13	80	25	8	5
F-24	25	15	5	4
F-38	25	10	5	4
F-48	20	15	5	5
M-31	25	25	6	5
M-39	25	15	6	5
M-70	30	25	4	4

PLM ANALYSIS

	CHRYSOTILE-VOLUME %-STANDARD	CHRYSOTILE-VOLUME %-REPLICATE	RELEASABILITY RATING-STANDARD	RELEASABILITY RATING-REPLICATE
	DATA	DATA	DATA	DATA
SAMPLE NO.				
F-12	85	85	6	7
F-26	23	25	5	6
F-60	20	20	5	5
F-63	20	20	6	5
M-30	25	25	5	6
M-42	30	25	6	6
M-65	85	85	5	5

PLM ANALYSIS

	CHRYSOTILE-VOLUME %-STANDARD	CHRYSOTILE-VOLUME %-EXTERNAL QA	RELEASABILITY RATING-STANDARD	RELEASABILITY RATING-EXTERNAL QA
	DATA	DATA	DATA	DATA
SAMPLE NO.				
F-34	27	15	4	3
F-39	25	3	5	3
F-48	20	3	5	3
M-39	25	15	6	3
M-50	30	15	6	3
M-59	25	15	5	3
M-70	30	17	4	3
M-79	25	15	6	4

APPENDIX D

Data Listings

APPENDIX D-1

DATA LISTING FOR AIR SAMPLES

Period	School	Site	Site Type	Sampling Time	Analysis Type	Filter ID (Millipore)	PCM No Fibers	PCM fib/m3	TEM No Fibers	TEM fib/m3	TEM ng/m3	Filter ID (Nuclepore)	SEM No fibers 2,000x	SEM No fibers 20,000x	SEM fib/m3	SEM ng/m3
1	1	1	NA	35	S	S20	37	1.20E+04	62	3.20E+05	1.60E+00	RTI19	0	0	0.00E+00	0.00E+00
1	1	1	NA	35	D	S20	33	1.10E+04	.	.	.		.	.	.	.
1	1	2	A	35	S	M17	28	1.10E+04	7	1.00E+04	6.00E-02	RTI6	0	0	0.00E+00	0.00E+00
1	1	2	A	35	R	M17	27	1.10E+04	.	.	.		.	.	.	.
1	1	6	A	35	S	S19	59	2.10E+04	4	6.00E+03	1.00E-01	RTI4	0	0	0.00E+00	0.00E+00
1	1	6	A	35	R		.	.	.	.		RTI4	0	0	0.00E+00	0.00E+00
1	1	6	A	35	D	S19	54	1.90E+04	.	.	.		.	.	.	.
1	1	7	O	35	S	F4	1	4.00E+02	18	2.90E+04	1.60E-01	RTI15	0	0	0.00E+00	0.00E+00
1	1	7	O	35	R	F4	4	1.00E+03	.	.	.		.	.	.	.
1	1	7	O	35	D	F4	.	.	24	3.90E+04	2.20E-01	RTI15	0	0	0.00E+00	0.00E+00
1	2	1	NA	35	S	M23	33	8.80E+03	15	1.80E+04	9.70E-02		.	.	.	.
1	2	1	NA	35	R	M23	37	9.90E+03	.	.	.		.	.	.	.
1	2	1	NA	35	D	M23	.	.	22	2.60E+04	1.30E-01		.	.	.	.
1	2	2	A	35	S	S27	80	3.30E+04	8	1.00E+04	3.00E-01	RTI9	0	0	0.00E+00	0.00E+00
1	2	2	A	35	R	S27	55	2.30E+04	.	.	.		.	.	.	.
1	2	3	NA	35	S	M21	25	9.80E+03	14	2.40E+04	8.30E-02	RTI5	0	0	0.00E+00	0.00E+00
1	2	3	NA	35	R	M21	34	1.30E+04	.	.	.	RTI5	0	0	0.00E+00	0.00E+00
1	2	4	A	35	S	S26	37	1.10E+04	2	3.00E+03	1.00E-02	RTI14	0	0	0.00E+00	0.00E+00
1	2	4	A	35	D		.	.	.	.	.	RTI14	0	0	0.00E+00	0.00E+00
1	2	5	A	35	S	M22	33	1.10E+04	128	3.86E+05	2.09E+00	RTI16	1	0	7.00E+02	7.00E+01
1	2	5	A	35	R	M22	.	.	30	4.50E+04	4.60E-01		.	.	.	.
1	2	5	A	35	D	M22	40	1.40E+04	.	.	.	RTI16	0	0	0.00E+00	0.00E+00
1	2	6	A	35	S	S28	51	1.70E+04	8	1.00E+04	1.00E+00	RTI3	0	0	0.00E+00	0.00E+00
1	2	6	A	35	R	S28	.	.	120	2.26E+05	1.13E+00		.	.	.	.
1	2	6	A	35	D	S28	47	1.50E+04	.	.	.		.	.	.	.
1	2	7	O	35	S	F8	2	7.00E+02	2	3.00E+03	9.00E-03	RTI8	0	0	0.00E+00	0.00E+00
1	2	7	O	35	R		.	.		.	.	RTI8	0	0	0.00E+00	0.00E+00
1	2	7	O	35	D	F8	17	5.60E+03	.	.	.		.	.	.	.
1	3	1	A	35	S	M18	33	1.30E+04	17	2.90E+04	2.60E-01	RTI18	0	0	0.00E+00	0.00E+00
1	3	1	A	35	R		.	.		.	.	RTI18	0	0	0.00E+00	0.00E+00
1	3	1	A	35	D	M18	.	.	29	5.00E+04	2.40E-01		.	.	.	.
1	3	2	NA	35	S	M19	67	2.20E+04	0	0.00E+00	0.00E+00	RTI13	0	0	0.00E+00	0.00E+00
1	3	3	A	35	S	S23	130	3.79E+04	104	1.75E+05	1.12E+00	RTI1	0	0	0.00E+00	0.00E+00
1	3	3	A	35	R		.	.	.	.	.	RTI1	0	0	0.00E+00	0.00E+00
1	3	4	A	35	S	S25	83	3.00E+04	4	6.00E+03	6.00E-02	RTI17	0	0	0.00E+00	0.00E+00
1	3	4	A	35	R		.	.	.	.	.	RTI17	0	0	0.00E+00	0.00E+00
1	3	4	A	35	D	S25	.	.	4	6.00E+03	3.00E-02	RTI17	0	0	0.00E+00	0.00E+00
1	3	5	NA	35	S	M20	91	3.90E+04	41	7.80E+04	5.30E-01	RTI20	1	0	8.00E+02	2.00E+03
1	3	5	NA	35	R	M20	.	.	13	2.50E+04	2.60E-01		.	.	.	.
1	3	5	NA	35	D	M20	95	4.10E+04	.	.	.	RTI20	0	0	0.00E+00	0.00E+00
1	3	6	A	35	S	S24	76	3.00E+04	66	1.10E+05	7.60E-01	RTI7	0	0	0.00E+00	0.00E+00
1	3	6	A	35	R	S24	81	3.20E+04	.	.	.		.	.	.	.
1	3	6	A	35	D		.	.	.	.	.	RTI7	0	0	0.00E+00	0.00E+00
1	3	7	O	35	S	F6	1	3.00E+02	1	1.00E+03	5.00E-03	RTI2	0	0	0.00E+00	0.00E+00
1	3	7	O	35	R	F6	1	3.00E+02	5	6.00E+03	4.00E-02		.	.	.	.
1	4	1	A	35	S	S21	183	3.91E+04	34	3.20E+04	2.80E-01					.
1	4	1	A	35	R	S21	146	3.12E+04	.	.	.		.		.	.
1	4	1	A	35	D	S21	.	.	181	1.71E+05	1.11E+00		.	.	.	
1	4	2	A	35	S	S22	50	1.60E+04	5	7.00E+03	1.00E-01		.	.	.	.
1	4	2	A	35	R	S22	.	.	50	7.00E+04	4.10E-01			.	.	
1	4	2	A	35	D	S22	48	1.50E+04	.	.	.		.	.	.	.
1	4	3	O	35	S	F5	7	2.00E+03	49	7.00E+04	5.90E-01		.	.	.	.
2	1	1	NA	35	S	G22	0	0.00E+00	0	0.00E+00	0.00E+00	RTI33	0	0	0.00E+00	0.00E+00
2	1	1	NA	35	R	G22	0	0.00E+00	4	6.00E+03	5.00E-02		.	.	.	.
2	1	1	NA	35	E	G22	.	.	1	2.00E+03	2.00E-02		.	.	.	.
2	1	1	NA	35	D		.		.	.	.	RTI33	0	0	0.00E+00	0.00E+00

Site Type
- A = asbestos
- NA = non-asbestos
- O = outdoor
- FB = field blank
- LB = lab blank

Analysis Type
- S = standard
- R = replicate
- D duplicate
- E empty (blank)

Period	School	Site	Site Type	Sampling Time	Analysis Type	Filter ID (Millipore)	PCM No Fibers	PCM fib/m^3	TEM No Fibers	TEM fib/m^3	TEM ng/m^3	Filter ID (Nuclepore)	SEM No fibers 2,000x	SEM No fibers 20,000x	SEM fib/m^3	SEM ng/m^3
2	1	7	O	35	S	G23	1	3.00E+02	2	3.00E+03	2.00E-02		.	.	.	.
2	1	7	O	35	R	G23	5	1.00E+03	.	.	.		.	.	.	.
2	1	9	A	35	S	K23	23	7.50E+03	102	1.48E+06	1.04E+01	RTI32	3	1	3.00E+03	6.00E+00
2	1	9	A	35	R		.	.	.	.	.	RTI32	1	2	2.00E+03	4.00E-01
2	1	9	A	35	D	K23	.	.	152	2.20E+06	1.46E+01		.	.	.	.
2	1	10	A	35	S		.	.	.	.	.	RTI25	0	0	0.00E+00	0.00E+00
2	2	1	NA	35	S	K14	0	0.00E+00	14	2.00E+04	3.40E-01		.	.	.	.
2	2	1	NA	35	R	K14	.	.	10	1.40E+04	1.00E-01		.	.	.	.
2	2	3	NA	35	S	K12B	4	1.00E+03	42	5.00E+04	3.40E-01	RTI37	0	0	0.00E+00	0.00E+00
2	2	3	NA	35	R	K12B	6	2.00E+03	.	.	.		.	.	.	.
2	2	7	O	35	S	B8	10	3.60E+03	0	0.00E+00	0.00E+00		.	.	.	.
2	2	7	O	35	R	B8	4	1.00E+03	.	.	.		.	.	.	.
2	2	8	A	35	S	G14	5	1.00E+03	55	5.00E+05	4.50E+00	RTI42	3	0	2.00E+03	2.00E+02
2	2	8	A	35	R	G14	18	5.20E+03	.	.	.		.	.	.	.
2	2	8	A	35	D	G14	.	.	39	3.50E+05	4.10E+00	RTI42	0	0	0.00E+00	0.00E+00
2	2	9	A	35	S	K15	2	7.00E+02	120	4.14E+06	2.49E+01	RTI36	3	0	2.00E+03	5.00E+01
2	2	9	A	35	R	K15	.	.	102	3.51E+06	2.21E+01	RTI36	6	1	6.00E+03	2.00E+01
2	2	10	A	35	S	G15	20	6.40E+03	200	9.92E+06	8.13E+01	RTI40	4	0	3.00E+03	1.00E+01
2	2	11	A	35	S	K13B	12	3.50E+03	53	6.80E+04	5.40E-01	RTI39	2	0	1.00E+03	4.00E+00
2	2	11	A	35	R	K13B	5	1.00E+03	.	.	.		.	.	.	.
2	2	11	A	35	E	K13B		.	0	0.00E+00	0.00E+00		.	.	.	.
2	2	11	A	35	D	K13B	.	.	43	5.50E+04	5.50E-01	RTI39	0	0	0.00E+00	0.00E+00
2	3	2	NA	35	S	B1	0	0.00E+00	17	2.40E+04	1.90E-01	RTI34	0	0	0.00E+00	0.00E+00
2	3	2	NA	35	R		.	.	.	.	.	RTI34	1	0	6.00E+02	5.00E+00
2	3	2	NA	35	D	B1	2	6.00E+02	6	9.00E+03	4.00E-01		.	.	.	.
2	3	5	NA	35	S	K7	2	6.00E+02	4	6.00E+03	8.00E-02	RTI31	0	0	0.00E+00	0.00E+00
2	3	5	NA	35	D	K7	0	0.00E+00	.	.	.		.	.	.	.
2	3	7	O	35	S	B9	6	2.00E+03	8	1.00E+04	4.00E-01	RTI35	0	0	0.00E+00	0.00E+00
2	3	7	O	35	D	B9	.	.	21	2.70E+04	1.90E-01		.	.	.	.
2	3	8	A	35	S	B2	22	7.30E+03	0	0.00E+00	0.00E+00	RTI21	2	1	2.00E+03	3.00E+02
2	3	8	A	35	R	B2	2	7.00E+02	49	7.20E+04	8.30E-01		.	.	.	.
2	3	8	A	35	D		.	.	.	.	.	RTI21	1	0	7.00E+02	3.00E+02
2	3	9	A	35	S	G7	16	6.90E+03	120	1.61E+07	1.41E+02	RTI23	8	5	8.50E+03	3.30E+02
2	3	9	A	35	E	G7	.	.	1	3.00E+03	1.00E-02			.	.	.
2	3	10	A	35	S	G6	6	2.00E+03	103	1.02E+07	6.32E+01			.	.	
2	3	10	A	35	D	G6	1	3.00E+02	.	.	.		.	.	.	.
2	4	3	O	35	S	G25	1	3.00E+02	0	0.00E+00	0.00E+00	RTI30	0	0	0.00E+00	0.00E+00
2	4	3	O	35	R	G25	.	.	11	9.90E+04	8.60E-01		.	.	.	
2	4	3	O	35	D	G25	0	0.00E+00		.	.					
2	4	4	A	35	S		.	.	.	.	.	RTI28	10	0	8.70E+03	1.30E+02
2	4	5	A	35	S		.	.	.	.	.	RTI27	7	1	7.00E+03	8.00E+02
2	4	5	A	35	R		.	.	.	.	.	RTI27	3	2	4.00E+03	3.00E+01
2	4	6	A	35	S	K24	3	9.00E+02	135	1.22E+07	1.39E+02	RTI26	14	0	1.10E+04	3.80E+02
2	4	6	A	35	R	K24	.	.	186	1.68E+07	1.41E+02	RTI26	1	0	8.00E+02	2.00E+00
2	4	6	A	35	D	K24	7	2.00E+03	.	.	.		.	.	.	.
3	1	1	NA	35	S	DG19	40	1.20E+04	19	2.50E+04	1.50E-01	DG18	0	0	0.00E+00	0.00E+00
3	1	1	NA	35	R	DG19	25	7.30E+03	74	9.50E+04	8.60E-01		.	.	.	.
3	1	6	A	35	S	MG16	15	4.80E+03	8	1.00E+04	9.00E-02	MG17	0	0	0.00E+00	0.00E+00
3	1	6	A	35	R	MG16	.	.	8	1.00E+04	1.00E-01	MG17	0	0	0.00E+00	0.00E+00
3	1	6	A	35	D	MG16	26	8.30E+03	.	.	.	MG17	0	0	0.00E+00	0.00E+00
3	1	7	O	35	S		.	.	.	.	.	MG19	0	0	0.00E+00	0.00E+00
3	2	1	NA	35	S	DG31	4	1.00E+03	4	2.00E+04	9.00E-02		.	.	.	
3	2	1	NA	35	D	DG31	7	2.00E+03	.	.	.		.	.	.	.
3	2	2	A	35	S	DG29	11	3.50E+03	0	0.00E+00	0.00E+00	DG30	0	0	0.00E+00	0.00E+00
3	2	2	A	35	R	DG29	6	2.00E+03	.	.			.	.	.	.
3	2	2	A	35	D		.	.	.	.	.	DG30	0	0	0.00E+00	0.00E+00
3	2	3	NA	35	S	DG27	.	.	0	0.00E+00	0.00E+00	DG28	0	0	0.00E+00	0.00E+00
3	2	3	NA	35	R		.	.	.	.	.	DG28	0	0	0.00E+00	0.00E+00

Period	School	Site	Site Type	Sampling Time	Analysis Type	Filter ID (Millipore)	PCM No Fibers	PCM fib/m³	TEM No Fibers	TEM fib/m³	TEM ng/m³	Filter ID (Nuclepore)	SEM No fibers 2,000x	SEM No fibers 20,000x	SEM fib/m³	SEM ng/m³
3	2	4	A	35	S	MG33	11	3.50E+03	1	5.00E+03	2.00E-02	MG34	0	0	0.00E+00	0.00E+00
3	2	4	A	35	R		.	.	.	.	.	MG34	0	0	0.00E+00	0.00E+00
3	2	4	A	35	D	MG33	.	.	6	3.00E+04	2.00E-01		.	.	.	.
3	2	5	A	35	S	MG31	9	3.00E+03	6	9.00E+03	1.00E-01	MG32	0	0	0.00E+00	0.00E+00
3	2	5	A	35	R	MG31	.	.	47	6.70E+04	2.90E-01		.	.	.	
3	2	5	A	35	D	MG31	36	1.20E+04	.	.	.		.	.	.	.
3	2	6	A	35	S	DG33	14	4.20E+03	5	7.00E+03	7.00E-01	DG32	0	0	0.00E+00	0.00E+00
3	2	6	A	35	R		.	.	.	.	.	DG32	0	0	0.00E+00	0.00E+00
3	2	6	A	35	D	DG33	.	.	7	9.00E+03	4.00E-02	DG32	0	0	0.00E+00	0.00E+00
3	2	7	O	35	S			.	.	.	.	MG30	0	0	0.00E+00	0.00E+00
3	3	1	A	35	S	MG24	28	8.20E+03	8	5.00E+04	2.00E-01	MG23	1	0	7.00E+02	1.00E+00
3	3	1	A	35	R		.	.	.	.	.	MG23	C	0	0.00E+00	0.00E+00
3	3	2	NA	35	S	DG21	11	4.10E+03	5	8.00E+03	4.00E-02	DG22	0	0	0.00E+00	0.00E+00
3	3	2	NA	35	D	DG21	11	4.10E+03	8	1.00E+04	8.00E-02	DG22	0	0	0.00E+00	0.00E+00
3	3	3	A	35	S	MG25	9	4.00E+03	8	1.00E+04	2.00E-01	MG26	0	0	0.00E+00	0.00E+00
3	3	3	A	35	R	MG25	10	4.20E+03	14	2.60E+04	1.80E-01		.	.	.	.
3	3	3	A	35	D		.	.	.	.	.	MG26	0	0	0.00E+00	0.00E+00
3	3	5	NA	35	S	DG23	3	1.00E+03	1	1.00E+03	1.00E-02	DG24	0	0	0.00E+00	0.00E+00
3	3	5	NA	35	R	DG23	13	4.30E+03	.	.	.		.	.	.	.
3	3	6	A	35	S	DG25	11	3.30E+03	11	1.50E+04	4.60E-01	DG26	0	0	0.00E+00	0.00E+00
3	3	6	A	35	D	DG25	0	0.00E+00	.	.	.		.	.	.	.
3	3	7	O	35	S	MG27	9	3.00E+03	15	2.10E+04	1.00E-01	MG28	0	0	0.00E+00	0.00E+00
3	3	7	O	35	R		.	.	.	.	.	MG28	0	0	0.00E+00	0.00E+00
3	3	7	O	35	D	MG27	26	8.30E+03	.	.	.		.		.	.
3	4	2	A	35	S	DG20	13	3.80E+03	4	5.00E+03	4.00E-02		.		.	.
3	4	2	A	35	D	DG20	.	.	9	1.00E+04	6.00E-02		.	.	.	
3	4	3	O	35	S	MG22	6	2.00E+03	12	1.70E+04	1.30E-01		.	.	.	.
3	4	3	O	35	D	MG22	.	.	15	2.10E+04	1.60E-01		.	.	.	.
4	1	1	NA	35	S	L20	125	4.00E+04	39	5.50E+04	2.40E-01	L21	0	0	0.00E+00	0.00E+00
4	1	1	NA	35	R	L20	81	2.60E+04	.	.	.		.	.	.	.
4	1	2	A	35	S	J8	1	3.00E+02	6	3.00E+04	2.00E-01	J9	0	0	0.00E+00	0.00E+00
4	1	2	A	35	R		.	.	.	.	.	J9	0	0	0.00E+00	0.00E+00
4	1	2	A	35	D	J8	2	6.00E+02	.	.	.	J9	0	0	0.00E+00	0.00E+00
4	1	6	A	35	S	D23	2	6.00E+02	20	2.80E+04	1.50E-01	D22	0	0	0.00E+00	0.00E+00
4	1	6	A	35	D	D23	.	.	57	8.10E+04	4.70E-01		.	.	.	.
4	1	7	O	35	S	D21	0	0.00E+00	3	4.00E+03	8.00E-02	D20	0	0	0.00E+00	0.00E+00
4	1	7	O	35	R	D21	.	.	3	4.00E+03	2.00E-02		.	.	.	.
4	1	7	O	35	D	D21	3	1.00E+03	.	.	.		.		.	.
4	2	1	NA	35	S	L29	322	9.38E+04	10	1.30E+04	6.50E-02		.	.	.	.
4	2	1	NA	35	D	L29	.	.	6	8.00E+03	4.00E-02		.	.	.	.
4	2	2	A	35	S	L30	148	4.89E+04	77	1.10E+05	9.30E-01	L31	0	0	0.00E+00	0.00E+00
4	2	2	A	35	R	L30	103	3.40E+04	.	.	.	L31	0	0	0.00E+00	0.00E+00
4	2	2	A	35	D	L30	.	.	18	2.60E+04	1.40E-01		.	.	.	.
4	2	3	NA	35	S	J13	191	6.12E+04	10	1.40E+04	8.50E-02	J12	0	0	0.00E+00	0.00E+00
4	2	3	NA	35	D	J13	94	3.00E+04	.	.	.	J12	0	0	0.00E+00	0.00E+00
4	2	4	A	35	S	D36	46	1.50E+04	2	3.00E+03	2.00E-02	D37	0	0	0.00E+00	0.00E+00
4	2	4	A	35	R	D36	.	.	5	7.00E+03	3.00E-02		.	.	.	.
4	2	5	A	35	S	L33	63	2.00E+04	5	7.00E+03	3.00E-02	L32	0	0	0.00E+00	0.00E+00
4	2	5	A	35	R		.	.		.	.	L32	0	0	0.00E+00	0.00E+00
4	2	5	A	35	D	L33	60	1.90E+04	.	.	.		.	.	.	.
4	2	6	A	35	S	D34	11	3.20E+03	1	1.00E+03	8.00E-03	D35	0	0	0.00E+00	0.00E+00
4	2	6	A	35	R	D34	8	2.00E+03	.	.	.		.	.	.	.
4	2	7	O	35	S	D32	0	0.00E+00	13	1.70E+04	8.50E-02	D33	0	0	0.00E+00	0.00E+00
4	2	7	O	35	R		.	.	.	.	.	D33	0	0	0.00E+00	0.00E+00

Period	School	Site	Site Type	Sampling Time	Analysis Type	Filter ID (Millipore)	PCM No Fibers	PCM fib/m^3	TEM No Fibers	TEM fib/m^3	TEM ng/m^3	Filter ID (Nuclepore)	SEM No fibers 2,000x	SEM No fibers 20,000x	SEM fib/m^3	SEM ng/m^3
4	3	1	A	35	S	L23	66	2.10E+04	22	3.10E+04	2.30E-01	L24	0	0	0.00E+00	0.00E+00
4	3	1	A	35	D	L23	.	.	6	9.00E+03	3.00E-01		.	.	.	.
4	3	2	NA	35	S	L25	155	5.84E+04	6	1.00E+04	3.00E-01	L26	0	0	0.00E+00	0.00E+00
4	3	2	NA	35	R	L25	47	1.80E+04	11	1.80E+04	7.60E-02		.	.	.	.
4	3	3	A	35	S	L27	227	7.99E+04	88	9.60E+05	5.80E+00	L28	0	0	0.00E+00	0.00E+00
4	3	3	A	35	D	L27	150	5.28E+04	.	.	.	L28	0	0	0.00E+00	0.00E+00
4	3	4	A	35	S	J11	42	1.10E+04	0	0.00E+00	0.00E+00	J10	0	0	0.00E+00	0.00E+00
4	3	4	A	35	R	J11	.	.	5	6.00E+03	5.00E-02		.	.	.	.
4	3	5	NA	35	S			.	.	.	.	D30	0	0	0.00E+00	0.00E+00
4	3	5	NA	35	R		.	.	.	.	.	D30	0	0	0.00E+00	0.00E+00
4	3	6	A	35	S	D29	1	3.00E+02	33	4.30E+04	2.10E-01	D28	0	0	0.00E+00	0.00E+00
4	3	6	A	35	R	D29	7	2.00E+03	.	.	.	D28	0	0	0.00E+00	0.00E+00
4	3	7	O	35	S	D27	3	1.00E+03	2	3.00E+03	1.00E-02	D26	0	0	0.00E+00	0.00E+00
4	3	7	O	35	R	D27	0	0.00E+00	.	.	.		.	.	.	.
4	3	7	O	35	D		.	.	.	.	.	D26	0	0	0.00E+00	0.00E+00
4	4	1	A	35	S	D25	2	5.00E+02	46	5.40E+04	3.20E-01		.	.	.	.
4	4	1	A	35	R	D25	.	.	7	8.00E+03	5.00E-02		.	.		
4	4	2	A	35	S	L22	210	5.61E+04	29	1.20E+05	6.00E-01		.	.	.	.
4	4	2	A	35	R	L22	113	3.02E+04	.	.	.		.	.	.	
4	4	3	O	35	S	D24	0	0.00E+00	14	1.70E+04	8.10E-02		.		.	.
4	4	3	O	35	D	D24		.	19	2.20E+04	1.40E-01		.	.	.	.

APPENDIX D-2

DATA LISTING OF PLM RESULTS

ID	School	Site	LOCNUM	Code	CHRYS%	AMOS%	OTHABS	GLSWOOL	FIBGLS	CELLU	OTHFIB	PERLITE	VERMIC	OTHNFIB	RELEASE
F10	4	1	1		.	.			.			.	.		.
F11	4	1	2		85	0	0	T	0	0	0	00	00	15	7
F12	4	1	3	A	85	0	0	T	0	0	0	00	00	15	6
F13	4	1	4		80	0	0	T	0	0	0	00	00	20	8
F14	4	1	3	B	85	0	0	T	0	0	0	00	00	15	7
F15	4	1	6	A	.	.			.						.
F16	4	1	5		.	.			.			.	.		.
F17	4	1	6	B	.	.			.			.	.		.
F18	4	2	1		80	0	0	0	0	0	0	00	00	20	3
F19	4	2	2		85	0	0	0	0	0	0	00	00	15	4
F20	4	2	3	B	.	.			.			.			.
F21	4	2	4		.	.			.			.			.
F22	4	2	5		.	.			.			.	.		.
F23	4	2	6	B	85	0	0	0	0	0	0	00	00	15	5
F24	3	3	1		25	0	0	0	0	0	0	10	60	1 4	5
F25	3	3	2		.	.			.			.	.		.
F26	3	3	3	A	23	0	0	0	0	0	0	10	61	4 2	5
F27	3	3	4		25	0	0	0	0	0	0	10	61	4	5
F28	3	3	5		.	.			.			.	.		.
F29	3	6	3	A	.	.			.			.	.		.
F30	3	6	4		.	.			.			.	.		.
F31	3	6	3	B	.	.			.			.	.		.
F32	3	6	6	B	15	0	0	0	0	0	0	00	50	MIS	4
F33	3	4	1		.	.			.			.	.		.
F34	3	4	3	A	27	0	0	0	0	0	0	00	67	5 1	4
F35	3	4	6	A	.	.			.			.	.		.
F36	3	4	2		25	0	0	0	0	0	0	00	70	4 1	4
F37	2	5	1		.	.			.			.	.		.
F38	2	5	2		25	0	0	0	0	0	0	65	00	10	5
F39	2	5	3	A	25	0	0	0	0	0	0	65	00	10	5
F40	2	5	3	B	3	0	0	0	0	0	0	.	.	MIS	3
F41	2	5	4		30	0	0	0	0	0	0	60	00	10	5
F42	2	5	5		.	.			.			.			
F43	2	5	6	A	.	.			.				.		.
F44	2	5	6	B		.			.			.	.		.
F45	2	4	1		.	.			.			.	.		.
F46	2	4	2		.	.			.			.	.		.
F47	2	4	3	A	3	0	0	0	0	<1	0	.	.	MIS	3
F48	2	4	3	B	20	0	0	0	0	0	0	70	00	10	5
F49	2	4	4		20	0	0	0	0	0	0	70	00	10	5
F50	2	4	5		20	0	0	0	0	0	0	70	00	10	5
F51	2	4	6	A	.	.			.			.			.
F52	2	4	6	B	.	.			.			.	.		.
F53	2	2	1		20	0	0	0	0	0	0	70	00	10	5
F54	2	2	2		.	.							.		.
F55	2	2	3	A	.	.			.			.	.		.
F56	2	2	3	B	.	.			.			.			
F57	2	2	4		.	.			.			.	.		.
F58	2	2	5		20	0	0	0	0	0	0	70	00	10	5
F59	2	2	6	B	20	0	0	0	0	0	0	70	00	10	5
F60	2	2	6	A	20	0	0	0	0	0	0	70	00	10T	5
F61	2	6	1		20	0	0	0	0	0	0	70	00	10	6
F62	2	6	2		.	.			.			.	.		.
F63	2	6	3	A	20	0	0	0	0	0	0	70	00	10	6
F64	2	6	3	B	20	0	0	0	0	0	0	70	00	10T	5
F65	2	6	4		.	.			.			.	.		.
F66	2	6	5		20	0	0	0	0	T	0	70	00	10	5
F67	2	6	6	A	.				.				.		.
F68	2	6	6	B	.	.			.			.	.		.
M24	1	8	1		25	0	0	0	0	0	0	10	60	2 3	6
M25	1	8	2		.	.			.				.		.
M26	1	8	3	A	.	.			.			.	.		.

ID	School	Site	LOCNUM	Code	CHRYS% AMOS%	OTHABS	GLSWOOL	FIBGLS	CELLU	OTHFIB	PERLITE	VERMIC	OTHNFIB	RELEASE
M27	1	8	3	B	. .			.			.	.		.
M28	1	8	4		250	0	0	0	0	0	10	59	2 4	6
M29	1	8	5		. .			.			.	.		.
M30	1	8	6	A	250	0	0	0	0	0	9	60	2 4	5
M31	1	2	4		250	0	0	0	0	0	10	60	2 3	6
M32	1	2	1		. .			.			.	.		.
M33	1	2	5		250	0	0	0	0	0	10	60	2 3	6
M34	1	2	3	A	. .			.			.	.		.
M35	1	8	6	B	250	0	0	0	0	0	10	60	3 2	6
M36	1	2	3	B	. .			.			.	.		.
M37	1	2	6	A	150	0	0	0	0	0	00	60	MIS	3
M38	1	2	2		. .			.			.	.		.
M39	1	2	6	B	250	0	0	0	0	0	10	60	2 3	6
M40	1	6	1		. .			.			.	.		.
M41	1	6	2		250	0	0	0	0	0	10	60	2 3	6
M42	1	6	3	A	300	0	0	0	0	0	9	57	2 2	6
M43	1	6	3	B	250	0	0	0	0	0	12	56	2 5	6
M44	1	6	4		. .			.			.	.		.
M45	1	6	5		250	0	0	0	0	0	12	56	2 5	5
M46	1	6	6	A	. .			.						.
M47	1	6	6	B	. .			.			.	.		
M48	1	5	1		. .			.			.	.		.
M49	1	5	2		300	0	0	0	0	0	10	54	2 4	5
M50	1	5	3	A	300	0	0	0	0	0	10	54	2 4	6
M51	1	5	4		. .			.			.	.		.
M52	1	5	3	B	150	0	0	0	0	0	00	55	MIS	3
M53	1	5	6	A	. .			.			.	.		.
M54	1	5	5		250	0	0	0	0	0	10	58	2 5	6
M55	1	5	6	B	. .			.			.	.		.
M56	1	3	1		250	0	0	0	0	0	10	59	2 4	6
M57	1	3	3	A	150	0	0	0	0	0	00	55	MIS	3
M58	1	3	2		250	T	0	0	0	0	10	59	2 4	5
M59	1	3	3	B	250	0	0	0	0	0	10	58	2 5	5
M60	1	3	4		. .			.			.	.		
M61	1	3	6	A	. .			.			.	.		.
M62	1	3	5		.			.				.		.
M63	1	3	6	B	. .			.				.		.
M64	4	2	3	A	. .			.			.	.		.
M65	4	2	6	A	850	0	T	0	0	0	00	00	15	5
M66	3	1	1		. .			.			.	.		.
M67	3	1	2		250	0	0	0	0	0	00	70	1 4	3
M68	3	1	3	A	170	0	0	0	0	0	00	50	MIS	3
M69	3	1	4		300	0	0	0	0	0	00	65	5	4
M70	3	1	3	B	300	0	0	0	0	0	00	66	3 1	4
M71	3	1	5		. . .			.			.	.		
M72	3	1	6	A	. .			.			.	.		.
M73	3	1	6	B	. .			.			.	.		.
M74	3	3	3	B	250	0	0	0	0	0	10	60	1 4	6
M75	3	3	6	A	. .			.			.	.		.
M76	3	3	6	B	. .			.			.			
M77	3	6	1		. .			.			.	.		.
M78	3	6	2		250	0	0	0	0	0	10	60	1 4	6
M79	3	6	6	A	250	0	0	0	0	0	10	60	1 4	6
M80	3	6	5		250	0	0	0	0	0	10	61	1 3	6
M81	3	4	3	B	150	0	0	0	0	0	00	50	MIS	3
M82	3	4	4		. .			.			.	.		.
M83	3	4	5		250	0	0	0	0	T	00	72	2 1	4
M84	3	4	6	B	. .			.			.	.		.

APPENDIX E

Summary of Sample Results For Each School and Site

Table E-1. Chrysotile Fiber Concentration (Fibers/m^3) Measured by TEM at Each School and Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

			PERIOD			
			BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
			TEM-CHRYS-FIBERS/M**3	TEM-CHRYS-FIBERS/M**3	TEM-CHRYS-FIBERS/M**3	TEM-CHRYS-FIBERS/M**3
SCHOOL	SITE	TYPE				
1	1	NON-ASBESTOS	320000	3000	60000	55000
	2	ASBESTOS	10000	.	.	30000
	6	ASBESTOS	6000	.	10000	54000
	7	OUTDOOR	34000	3000	.	4000
	9	ASBESTOS	.	1800000	.	.
	10	ASBESTOS	.	.	.	.
2	1	NON-ASBESTOS	22000	17000	20000	10000
	2	ASBESTOS	10000	.	0	68000
	3	NON-ASBESTOS	24000	50000	0	14000
	4	ASBESTOS	3000	.	18000	5000
	5	ASBESTOS	220000	.	38000	7000
	6	ASBESTOS	120000	.	8000	1000
	7	OUTDOOR	3000	0	.	17000
	8	ASBESTOS	.	430000	.	.
	9	ASBESTOS	.	3800000	.	.
	10	ASBESTOS	.	9900000	.	.
	11	ASBESTOS	.	61000	.	.
3	1	ASBESTOS	39000	.	50000	20000
	2	NON-ASBESTOS	0	16000	9000	14000
	3	ASBESTOS	180000	.	16000	960000
	4	ASBESTOS	6000	.	.	3000
	5	NON-ASBESTOS	51000	6000	1000	.
	6	ASBESTOS	110000	.	15000	43000
	7	OUTDOOR	3500	18000	21000	3000
	8	ASBESTOS	.	36000	.	.
	9	ASBESTOS	.	16000000	.	.
	10	ASBESTOS	.	10000000	.	.
4	1	ASBESTOS	100000	.	.	31000
	2	ASBESTOS	38000	.	7500	120000
	3	OUTDOOR	70000	49000	19000	19000
	4	ASBESTOS	.	.	.	.
	5	ASBESTOS	.	.	.	.
	6	ASBESTOS	.	14000000	.	.

Table E-2. Chrysotile Mass Concentration (ng/m^3) Measured by TEM at Each School and Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

			PERIOD			
			BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
			TEM-CHRYS-NG/M**3	TEM-CHRYS-NG/M**3	TEM-CHRYS-NG/M**3	TEM-CHRYS-NG/M**3
SCHOOL	SITE	TYPE				
1	1	NON-ASBESTOS	1.60	0.02	0.50	0.24
	2	ASBESTOS	0.06	.	.	0.20
	6	ASBESTOS	0.10	.	0.09	0.31
	7	OUTDOOR	0.19	0.02	.	0.05
	9	ASBESTOS	.	12.00	.	.
	10	ASBESTOS	.	.	.	.
2	1	NON-ASBESTOS	0.11	0.22	0.09	0.05
	2	ASBESTOS	0.30	.	0.00	0.53
	3	NON-ASBESTOS	0.08	0.34	0.00	0.08
	4	ASBESTOS	0.01	.	0.11	0.02
	5	ASBESTOS	1.30	.	0.19	0.03
	6	ASBESTOS	1.10	.	0.37	0.01
	7	OUTDOOR	0.01	0.00	.	0.08
	8	ASBESTOS	.	4.30	.	.
	9	ASBESTOS	.	23.00	.	.
	10	ASBESTOS	.	81.00	.	.
	11	ASBESTOS	.	0.54	.	.
3	1	ASBESTOS	0.25	.	0.20	0.26
	2	NON-ASBESTOS	0.00	0.29	0.06	0.19
	3	ASBESTOS	1.10	.	0.19	5.80
	4	ASBESTOS	0.04	.	.	0.02
	5	NON-ASBESTOS	0.39	0.08	0.01	.
	6	ASBESTOS	0.76	.	0.46	0.21
	7	OUTDOOR	0.02	0.29	0.10	0.01
	8	ASBESTOS	.	0.41	.	.
	9	ASBESTOS	.	140.00	.	.
	10	ASBESTOS	.	63.00	.	.
4	1	ASBESTOS	0.69	.	.	0.18
	2	ASBESTOS	0.25	.	0.05	0.60
	3	OUTDOOR	0.59	0.43	0.14	0.11
	4	ASBESTOS	.	.	.	.
	5	ASBESTOS	.	.	.	.
	6	ASBESTOS	.	140.00	.	.

Table E-3. Chrysotile Fiber Concentration (Fibers/m^3) Measured by SEM at Each School and Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

			PERIOD			
			BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
			SEM-CHRYS-FIBERS/M**3	SEM-CHRYS-FIBERS/M**3	SEM-CHRYS-FIBERS/M**3	SEM-CHRYS-FIBERS/M**3
SCHOOL	SITE	TYPE				
1	1	NON-ASBESTOS	0	0	0	0
	2	ASBESTOS	0	.	.	0
	6	ASBESTOS	0	.	0	0
	7	OUTDOOR	0	.	0	0
	9	ASBESTOS	.	2500	.	.
	10	ASBESTOS	.	0	.	.
2	1	NON-ASBESTOS	.	.	.	.
	2	ASBESTOS	0	.	0	0
	3	NON-ASBESTOS	0	0	0	0
	4	ASBESTOS	0	.	0	0
	5	ASBESTOS	350	.	0	0
	6	ASBESTOS	0	.	0	0
	7	OUTDOOR	0	.	0	0
	8	ASBESTOS	.	1000	.	.
	9	ASBESTOS	.	4000	.	.
	10	ASBESTOS	.	3000	.	.
	11	ASBESTOS	.	500	.	.
3	1	ASBESTOS	0	.	350	0
	2	NON-ASBESTOS	0	300	0	0
	3	ASBESTOS	0	.	0	0
	4	ASBESTOS	0	.	.	0
	5	NON-ASBESTOS	400	0	0	0
	6	ASBESTOS	0	.	0	0
	7	OUTDOOR	0	0	0	0
	8	ASBESTOS	.	1300	.	.
	9	ASBESTOS	.	8500	.	.
	10	ASBESTOS	.	.	.	.
4	1	ASBESTOS	.	.	.	.
	2	ASBESTOS	.	.	.	.
	3	OUTDOOR	.	0	.	.
	4	ASBESTOS	.	8700	.	.
	5	ASBESTOS	.	5500	.	.
	6	ASBESTOS	.	5900	.	.

Table E-4. Chrysotile Mass Concentration (ng/m^3) Measured by SEM at Each School and Site Before, During and After Removal of the Asbestos-Containing Material During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

			PERIOD			
			BEFORE REMOVAL	DURING REMOVAL	SHORTLY AFTER REMOVAL	AFTER SCHOOL RESUMED
			SEM-CHRYS-NG/M**3	SEM-CHRYS-NG/M**3	SEM-CHRYS-NG/M**3	SEM-CHRYS-NG/M**3
SCHOOL	SITE	TYPE				
1	1	NON-ASBESTOS	0.00	0.00	0.00	0.00
	2	ASBESTOS	0.00	.	.	0.00
	6	ASBESTOS	0.00	.	0.00	0.00
	7	OUTDOOR	0.00	.	0.00	0.00
	9	ASBESTOS	.	3.20	.	.
	10	ASBESTOS	.	0.00	.	.
2	1	NON-ASBESTOS	.	.	.	.
	2	ASBESTOS	0.00	.	0.00	0.00
	3	NON-ASBESTOS	0.00	0.00	0.00	0.00
	4	ASBESTOS	0.00	.	0.00	0.00
	5	ASBESTOS	35.00	.	0.00	0.00
	6	ASBESTOS	0.00	.	0.00	0.00
	7	OUTDOOR	0.00	.	0.00	0.00
	8	ASBESTOS	.	100.00	.	.
	9	ASBESTOS	.	35.00	.	.
	10	ASBESTOS	.	10.00	.	.
	11	ASBESTOS	.	2.00	.	.
3	1	ASBESTOS	0.00	.	0.50	0.00
	2	NON-ASBESTOS	0.00	2.50	0.00	0.00
	3	ASBESTOS	0.00	.	0.00	0.00
	4	ASBESTOS	0.00	.	.	0.00
	5	NON-ASBESTOS	1000.00	0.00	0.00	0.00
	6	ASBESTOS	0.00	.	0.00	0.00
	7	OUTDOOR	0.00	0.00	0.00	0.00
	8	ASBESTOS	.	300.00	.	.
	9	ASBESTOS	.	330.00	.	.
	10	ASBESTOS	.	.	.	.
4	1	ASBESTOS	.	.	.	.
	2	ASBESTOS	.	.	.	.
	3	OUTDOOR	.	0.00	.	.
	4	ASBESTOS	.	130.00	.	.
	5	ASBESTOS	.	410.00	.	.
	6	ASBESTOS	.	190.00	.	.

Table E-5. Fiber Concentration (Fibers/m^3) Measured by PCM at Each School and Site Before, During and After Removal of the Asbestos-Containing Material. During Removal, "Asbestos" Sites were Located Immediately Outside the Barriers.

SCHOOL	SITE	TYPE	PERIOD: BEFORE REMOVAL — PCM FIBERS/M**3	DURING REMOVAL — PCM FIBERS/M**3	SHORTLY AFTER REMOVAL — PCM FIBERS/M**3	AFTER SCHOOL RESUMED — PCM FIBERS/M**3
1	1	NON-ASBESTOS	11000	0	9600	33000
	2	ASBESTOS	11000	.	.	450
	6	ASBESTOS	20000	.	6500	600
	7	OUTDOOR	700	650	.	500
	9	ASBESTOS	.	7500	.	.
	10	ASBESTOS	.	.	.	.
2	1	NON-ASBESTOS	9300	0	1500	94000
	2	ASBESTOS	28000	.	2800	41000
	3	NON-ASBESTOS	11000	1500	.	46000
	4	ASBESTOS	11000	.	3500	15000
	5	ASBESTOS	13000	.	7500	19000
	6	ASBESTOS	16000	.	4200	2600
	7	OUTDOOR	3100	2300	.	0
	8	ASBESTOS	.	3100	.	.
	9	ASBESTOS	.	700	.	.
	10	ASBESTOS	.	6400	.	.
	11	ASBESTOS	.	2300	.	.
3	1	ASBESTOS	13000	.	8200	21000
	2	NON-ASBESTOS	22000	300	4100	38000
	3	ASBESTOS	38000	.	4100	66000
	4	ASBESTOS	30000	.	.	11000
	5	NON-ASBESTOS	40000	300	2600	.
	6	ASBESTOS	31000	.	1600	1100
	7	OUTDOOR	300	2000	5600	500
	8	ASBESTOS	.	4000	.	.
	9	ASBESTOS	.	6900	.	.
	10	ASBESTOS	.	1100	.	.
4	1	ASBESTOS	35000	.	.	500
	2	ASBESTOS	15000	.	3800	43000
	3	OUTDOOR	2000	150	2000	0
	4	ASBESTOS	.	.	.	.
	5	ASBESTOS	.	.	.	.
	6	ASBESTOS	.	1400	.	.

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16. Abstract (Limit: 200 words)

Airborne asbestos levels were measured by transmission electron miscroscopy (TEM), scanning electron microscopy (SEM) and phase constrast microscopy (PCM) before, during and after removal of sprayed-on acoustical plaster from the ceilings of four suburban schools. Air samples were collected at three types of sites: indoor sites with asbestos-containing material (ACM), indoor sites without ACM (indoor control), and sites outside the building (outdoor control). Bulk samples of the ACM were collected prior to the removal and analyzed by polarized light microscopy (PLM). A vigorous quality assurance program was applied to all aspects of the study.

Airborne asbestos levels were low before (< 6 ng/m^3) and after removal (< 5 ng/m^3). Elevated, but still relatively low levels (up to 140 ng/m^3), were measured outside the work area during removal. This emphasizes the need for careful containment of the work area. TEM provided the clearest documentation of changes in airborne asbestos. SEM detected few fibers but showed a similar trend to TEM. PCM results were unrelated to either the TEM or SEM results and showed highest fiber concentrations during periods of student activity in both asbestos and non-asbestos-containing sites.

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