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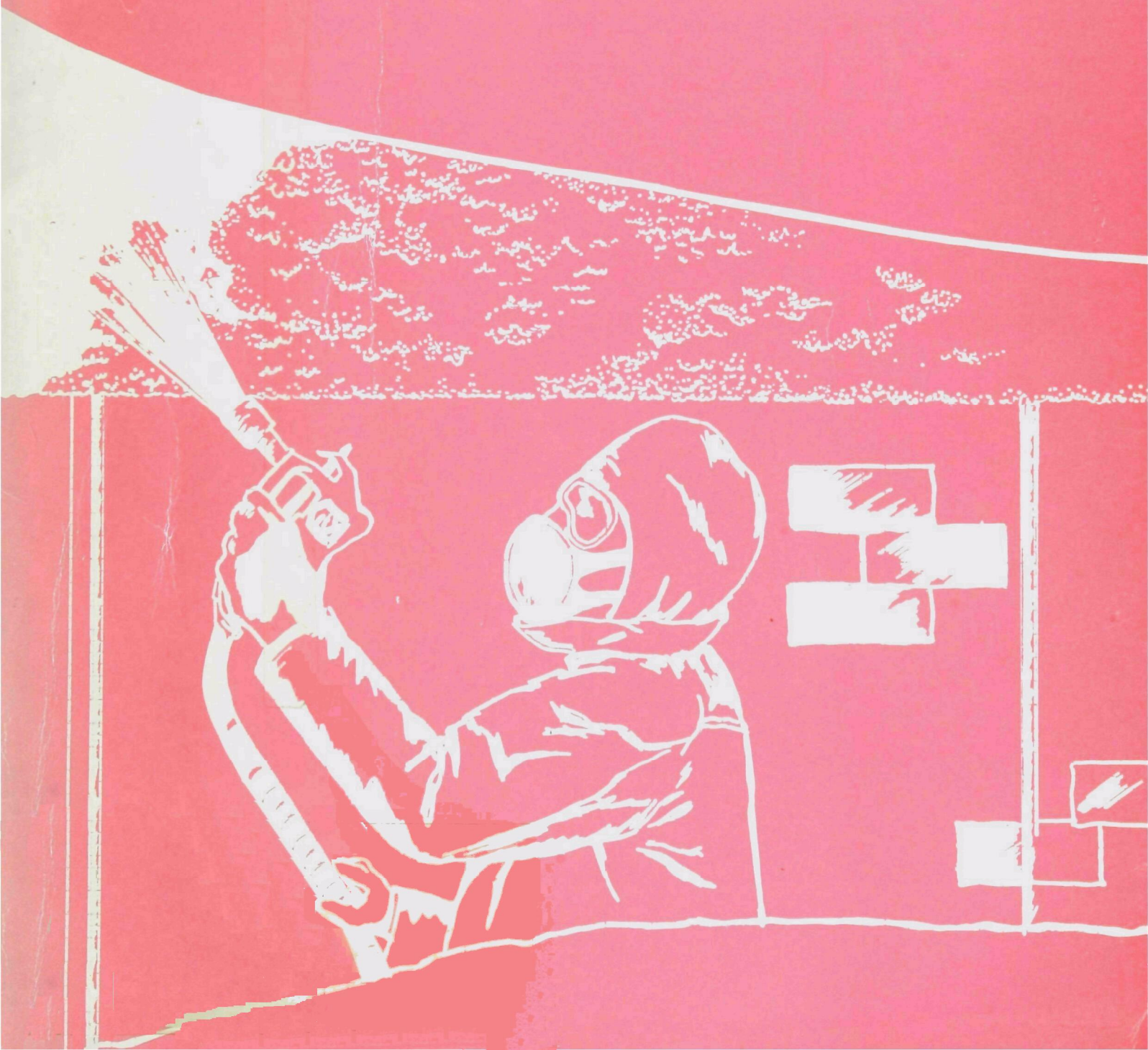
# EVALUATION OF ASBESTOS ABATEMENT TECHNIQUES

## PHASE 2: ENCAPSULATION WITH LATEX PAINT



July, 1986

# FINAL REPORT

on

# TASK 4

# EVALUATION OF ASBESTOS ABATEMENT TECHNIQUES PHASE 2: ENCAPSULATION WITH LATEX PAINT

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## EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency's "Friable Asbestos-Containing Materials in Schools, Identification and Notification Rule," as published in June 1984 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. This guidance was revised in 1985 based on information from field studies and experience gained by EPA and other organizations involved in asbestos control ("Guidance for Controlling Asbestos-Containing Materials in Buildings," EPA 560/5-85-024). The revised guidance emphasizes the immediate 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.

EPA has initiated a series of field studies to develop quantitative information on the relative merits of alternative abatement methods. The first of these studies examined the efficacy of removal of asbestos-containing materials from four schools in a suburban school system (USEPA 1985b). The second study, which is the subject of this report, examined the efficacy of encapsulation of asbestos-containing materials with a low sheen latex paint.

The primary objective of the study was to compare airborne asbestos levels before, during and after encapsulation of the asbestos-containing material. Airborne asbestos levels during encapsulation are of particular interest because it is often

assumed that respiratory protection is not required. The study objective was addressed by collecting air samples at a variety of sites in a suburban junior high school. The ceilings of the school were covered with a sprayed-on material containing chrysotile asbestos. School personnel followed EPA guidelines for containment of the work site and worker protection. There were four five-day periods of air sampling:

- Before encapsulation, while school was in session;
- During encapsulation;
- Immediately after encapsulation; and
- After school resumed.

Air samples were collected at 4 types of sites:

- Sites (rooms) with unpainted asbestos material on the ceiling scheduled for painting;
- Sites with asbestos material on the ceiling which had been painted 16 months prior to the study;
- Sites with no asbestos material (indoor control); and
- Outdoor sites on the roof of the building (outdoor control).

The air samples were analyzed by Transmission Electron Microscopy (TEM) to determine fiber and mass concentrations.

Bulk samples were collected at asbestos-containing sites prior to the encapsulation in order to characterize the asbestos containing material. Polarized Light Microscopy (PLM) was used to determine asbestos content and fiber releasability. (Fiber releasability is a subjective rating of the tendency of a material to release fibers.)

A vigorous quality assurance program was applied to all aspects of the study. System and performance audits were conducted in the field, sample traceability procedures were specified and followed, and a proportion of the samples were analyzed in duplicate (same preparation, different analyst), replicate (different preparation), or by a second laboratory.

The principal conclusions of the study are:

- High airborne asbestos levels can occur within the work site during encapsulation. Containment barriers

are necessary to prevent contamination of the rest of the building. Workers should have respiratory protection.

Evidence: Airborne asbestos levels recorded by mobile pumps and personal monitors worn by the painters measured levels of up to 13,000 ng/$m^3$ within the work site during painting. Airborne asbestos levels outside the work site were less than 4 ng/$m^3$.

- Airborne asbestos levels can be significantly reduced after encapsulation of material. From this study it is not possible to determine how long the reduction might last.

  Evidence: Airborne asbestos levels were highest before encapsulation (up to 111 ng/$m^3$) and lowest immediately after encapsulation (<0.5 ng/$m^3$). The reduction could be caused in part by the thorough cleaning that followed encapsulation. After school resumed there was a small, but statistically significant, increase in airborne asbestos levels (up to 4.5 ng/$m^3$).

A limited amount of information on variability of airbone asbestos levels within a site was collected. The results show that two samples collected from different locations within a site provide a more precise estimate of airborne asbestos concentration than two side-by-side samples. This should be considered when designing future studies.

# SECTION 1

# INTRODUCTION

The U.S. Environmental Protection Agency's "Friable Asbestos-Containing Materials in Schools, Identification and Notification Rule," as published in June 1984 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. This guidance was revised in 1985 based on information from field studies and experience gained by EPA and other organizations involved in asbestos control ("Guidance for Controlling Asbestos-Containing Materials in Buildings", EPA 560/5-85-024). The revised 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:

- Removal;
- Encapsulation; and
- 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.

EPA has initiated a series of field studies to develop quantitative information on the relative merits of alternative abatement methods. The first of these studies examined the efficacy of removal of asbestos-containing materials from four schools in a suburban school system (USEPA 1985b). The second study, which is the subject of this report, examined the efficacy of encapsulation of the asbestos-containing materials with a low sheen latex paint.

The primary objective of the study was to compare airborne asbestos levels before, during and after encapsulation of the asbestos-containing material. This objective was addressed by collecting air samples at a variety of sites within a suburban

junior high school. The ceilings of the school were covered with a sprayed-on material containing chrysotile asbestos. School personnel followed EPA's guidelines for containment of the work site and worker protection.

The principal conclusions of the study are given in Section 2. Section 3 provides information on the encapsulation project carried out by the school. Section 4 outlines the Quality Assurance (QA) procedures and Section 5 describes the sampling plan. These sections are followed by an account of the field survey (Section 6) and the methods of sample analysis (Section 7). The results of the statistical analyses are given in Section 8.

Appendices A through E contain excerpts from the QA Plan, field sampling and sample analysis protocols, results of the chemical analyses, and raw data listings.

## SECTION 2

## CONCLUSIONS

The principal conclusions from this study are listed below with a summary of the evidence on which they are based.

- High airborne asbestos levels can occur in the work site during encapsulation. Containment barriers are necessary to prevent contamination of the rest of the building. Workers should have respiratory protection.

  Evidence: Airborne asbestos levels recorded by mobile pumps and personal monitors worn by the painters measured levels of up to 13,000 ng/$m^3$ site during painting. Airborne asbestos levels outside the work site were less than 4 ng/$m^3$.

- Airborne asbestos levels can be significantly reduced after the material is encapsulated. The reduction could, however, be partly due to the thorough cleaning after encapsulation. From this study it is not possible to determine how long the effect of encapsulation might last.

  Evidence: Airborne asbestos levels were highest before encapsulation (up to 111 ng/$m^3$) and lowest immediately after encapsulation (<0.5 ng/$m^3$). After school resumed there was a small, but statistically significant, increase in air levels (up to 4.5 ng/$m^3$).

Other Issues:

The study also showed that airborne asbestos levels do vary from location to location within a sampling site (room). Two samples collected from different locations within a site provide a more precise estimate of airborne asbestos concentration than two side-by-side samples. This should be taken into account when designing future experiments.

## SECTION 3

## ENCAPSULATION METHODS

The encapsulation project was designed and implemented by the school district and was under their control. The school district provided information on the materials used and the method of application. Additional information on barrier construction and other aspects of the operation was gathered by the field crew.

All of the encapsulation work was handled by the school maintenance staff. The school consisted of four interconnected three-story, dome-shaped units. Each unit was isolated from the rest of the building during the encapsulation. Containment consisted of a single layer of polyethylene film sealed at the seams and ceiling line with duct tape (4 mil Vesqueen on the walls and 6 mil Vesqueen on the floors). The halls were lined with film to serve as access corridors. The single entrance to each containment area was equipped with a shower and a flap door on each side of the shower. The staff removed their work clothes on the inside, showered, and then put on their street clothes on the outside of the shower.

Two coats of paint were applied to the asbestos-containing ceiling material. The first coat was applied in one even coat. The second coat was applied by spraying in one direction then the other. The paint was a low sheen, white latex paint containing 31.7% vinyl acrylic resin. A sample of paint was analyzed by TEM to check that it did not contain asbestos. No asbestos was found. The paint was applied with a 433 Graco airless compressor. (Pump rate 3,000 psi, 3/4 gallon a minute volume, 7-21 tip on gun.) The spray gun was held approximately 8" from the surface. Fifteen (15) gallons of paint were applied per classroom (.02 gallons per square foot).

A negative air pressure system, which minimizes escape of asbestos fibers from the work area, was not used. However, a portable cooling system, equipped with HEPA filters, was operated to make working conditions more tolerable. It is likely that the cooling system did trap some asbestos fibers, removing them from the work area, and decreasing the chance of fibers escaping into the rest of the building. The effect of the cooling system on airborne asbestos levels was not a study objective and was not tested.

After encapsulation was completed, the polyethylene film was removed, bagged, and disposed of in an approved disposal area.

## SECTION 4

## QUALITY ASSURANCE

Project organization, personnel qualifications, field sampling, sample traceability, chemical analysis, data collection and analysis, documentation, and reporting are addressed in the project Quality Assurance Plan*. The objective of the Quality Assurance (QA) Program is to assure accuracy, precision, representativeness and completeness of the data. Appendix A contains excerpts from the QA plan.

The primary means for external monitoring of the project was provided by three performance and systems audits. These were carried out during the first, second and fourth sampling periods. A separate audit was not carried out during the third period because it took place almost immediately after the second sampling period. The audits were conducted on site to 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 and the accuracy of field flows was calculated using audit rotameter readings. Only one (11.1%) of 23 readings slightly exceeded the limits for relative accuracy of $\pm$10%. The average relative accuracy was 2.9% (standard deviation of 2.8%). During the first sampling period, only three pumps could be checked because school was in session and permission to audit was not readily given. Some minor problems or inconsistencies were detected during on-site logbook examinations and immediate corrective action was taken. Overall, the quality of data in the logbook and on traceability forms was rated by the auditor as very good.

The initial study design specified that a total of 247 Millipore filters were to be collected (73 field blanks and 174 exposed filters). A total of 250 filters were actually collected (73 field blanks and 177 exposed filters.) The additional three filters were collected during the encapsulation period. Another 12 filters were collected with either mobile or personal pumps during encapsulation. These were not specified in the QA Plan. Two of the 250 filters collected were badly damaged, presumably due to vandalism, and could not be analyzed. Another 24 filters (9.6%) suffered minor damage (pencil marks, scratches, finger prints, etc.) but were still suitable for analysis.

According to the QA Plan, 192 filters were designated for standard analysis, 30 filters for external QA analysis, 32 for replicate and 31 for duplicate analysis. Due to budget constraints

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*Evaluation of Asbestos Abatement Techniques, Phase 2, Quality Assurance Plan, submitted to EPA, August 1984.

standard TEM analyses were done on only 139 (72%) of the 192 filters. All 30 filters selected for external QA were analyzed. Twenty-six (26) filters (84%) were analyzed in duplicate, and 23 (74%) were analyzed in replicate. A total of eight field blanks and six laboratory blanks were analyzed at the main laboratory, and four laboratory blanks at the external QA laboratory. Six of the eight personal pump filters, and all four mobile pump filters were analyzed by TEM. One mobile pump filter was analyzed in duplicate. The filters that were not analyzed have been stored for possible future analysis when funds become available.

The results of the QA analyses are presented in detail in Section 7. The field and laboratory blanks show that background contamination (contamination of filters during manufacture, exposure during laboratory analysis, etc.) is insignificant ($<0.033$ $ng/m^3$). Correcting for it would not alter the estimates of airborne asbestos concentration which are reported to only one decimal place. The duplicate, replicate and external QA analyses are used to quantify the different sources of variability that contribute to the total variability associated with a TEM measurement. The results show that neither between-laboratory nor between-preparation variability contribute substantially to the total variability. It appears that most of the variability is due to other factors, such as the variability introduced by examining only a small fraction of the total filter area.

Thirty bulk samples were collected. All were of good quality and were analyzed by PLM.

## SECTION 5

## SAMPLING DESIGN

The primary objective of this study was to compare airborne asbestos levels before, during and after encapsulation of asbestos- containing material with latex paint. This objective was addressed by collecting air samples at a variety of sites in a suburban junior high school. The ceilings of the school were covered with a sprayed-on material containing chrysotile asbestos in a perlite matrix. The material had been applied to hallways, classrooms and other areas throughout the school. Some of the areas, in particular the hallways, had been painted previously with latex paint. Sites were chosen within the constraints of scheduling and accessibility in order to achieve the study objective.

All air samples were analyzed by TEM. A previous study (USEPA 1985b) concluded that transmission electron microscopy (TEM) provided the clearest documentation of changes in airborne asbestos levels.

Air samples were collected before and after the encapsulation work at four types of sites (Table 5.1):

- Sites (rooms) with unpainted asbestos material on the ceiling. These sites were scheduled for painting during this study*;
- Sites with asbestos material on the ceiling which had been painted 16 months prior to the study;
- Sites with no asbestos material (indoor controls); and
- Outdoor sites on the roof of the building (outdoor controls).

Sites in each of these categories were sampled three times:

- Before encapsulation while school was in session;
- Immediately after encapsulation; and
- After encapsulation, after school had resumed.

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*Note that these sites are referred to as unpainted asbestos sites throughout the study to distinguish them from the previously painted sites. After encapsulation the material at the unpainted asbestos sites is covered with paint.

Table 5.1. Sampling Plan for Air Samples Before and After Encapsulation

| School | Site | | Type | Number of Samples |
|---|---|---|---|---|
| 1 | 1. | Classroom | UA | 3 |
| | 2. | Classroom | UA | 2 |
| | 3. | Classroom | UA | 3 |
| | 4. | Classroom | UA | 3 |
| | 5. | Choir Room | UA | 3 |
| | 6. | Band Room | UA | 3 |
| | 7. | Classroom | UA | 2 |
| | 8. | Laboratory | UA | 3 |
| | 9. | Classroom | UA | 3 |
| | 10. | Classroom | UA | 2 |
| | 11. | Sewing Room | PA | 2 |
| | 12. | Classroom | PA | 2 |
| | 13. | Classroom | PA | 2 |
| | 14. | Auditorium | NA | 2 |
| | 15. | 2nd Floor Storeroom | NA | 2 |
| | 16. | Gym Equip. Room | NA | 2 |
| | 17. | Roof | O | 2 |

UA = Unpainted Asbestos
PA = Painted Asbestos
NA = Non-asbestos (Indoor Control)
O = Outdoor (Outdoor Control)

Each sample was taken over a period equivalent to five working days. The number of asbestos sites (10) was chosen to ensure that a five-fold or greater difference between airborne levels before and after encapsulation would be detected with a probability of at least 90%, assuming a coefficient of variation of 150% or less (Chesson et al. 1985).

Standard five-day air samples were collected at the outdoor site and at the non-asbestos sites during encapsulation. In addition, four other types of air samples were taken during encapsulation to provide information on levels both inside and outside the work area, and during the actual painting (Table 5.2):

- Samples at sites immediately outside the barriers separating the work area from the rest of the school (five-day samples).
- Samples at sites within the work area (five-day samples).
- Samples collected by mobile pumps. The pumps were carried from room to room as the painting progressed and were turned on only while painting was in progress.
- Personal pumps worn by two of the painters.

A small number of air samples were collected from a second school (Table 5.3) where the asbestos material had been painted three years previously. These samples were taken at the request of the school administrators to determine whether the asbestos material was adequately encapsulated. There was only one sampling period at the second school.

Air samples were collected with a pump equipped with two filters. Therefore two side-by-side samples were collected at each site. When extra pumps were available a second pump was placed on the opposite side of the room from the first pump. This was done to obtain information on the spatial variability in air levels within a room.

Bulk samples were collected from both schools to characterize the asbestos-containing material. The bulk samples were analyzed by polarized light microscopy (PLM) and rated for fiber releasability on a scale of 0 to 9. A rating of 9 indicates that the material has a very high potential for fiber release.

Table 5.2. Sampling Plan for Air Samples During Encapsulation

| School | | Site | Type | Number of Samples* |
|---|---|---|---|---|
| 1 | 3. | Classroom | UA | 3 |
| | 4. | Classroom | UA | 3 |
| | 9. | Classroom | UA | 3 |
| | 10. | Classroom | UA | 3 |
| | 14. | Auditorium | NA | 2 |
| | 15. | 2nd Floor Storeroom | NA | 2 |
| | 16. | Gym Equip. | NA | 2 |
| | 17. | Roof | O | 2 |
| | 18. | Classroom | UA | 3 |
| | 19. | Classroom | UA | 3 |
| | 20. | Classroom | UA | 3 |
| | 21. | Classroom | UA | 3 |
| | 22. | Side door-front foyer | OB | 2 |
| | 23. | Side door-rear foyer | OB | 2 |
| | 24. | Shower entrance | OB | 2 |
| | 25. | Shower entrance | OB | 2 |
| | 26. | Library at barrier door | OB | 2 |
| | 27. | Barrier between pod B and central area | OB | 2 |
| | Mobile Pumps - | 1st coat | M | 2 |
| | | 2nd coat | M | 2 |

UA = Unpainted Asbestos
PA = Painted Asbestos
M = Mobile
NA = Non-asbestos (Indoor Control)
O = Outdoor (Outdoor Control)
OB = Outside Barrier

*At sites where three samples were collected one sampler was turned off during actual painting in case there were clogging problems.

Table 5.3. Sampling Plan for Air Samples Collected at a Second School Where Asbestos-Containing Material had been Painted Three Years Previously

| School | Site | Type | Number of Samples |
|---|---|---|---|
| 2 | 1. Multipurpose Room | PA | 2 |
| | 2. Classroom | PA | 2 |
| | 3. Classroom | PA | 2 |
| | 4. Classroom | PA | 2 |
| | 5. Roof | O | 2 |

PA = Painted Asbestos
O = Outdoor Control

# SECTION 6

# FIELD SURVEY

## I. INTRODUCTION

The field survey included air sampling and bulk sampling. The statistical basis for the sampling plan is described in Section 5. 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 previous studies (USEPA 1983, 1985).

## II. AIR SAMPLING

Air sampling took place at the two schools as follows:

| | | Sampling | |
|---|---|---|---|
| Sampling Period | School | Dates | Time |
| 1 - Before encapsulation, School in session | 1 and 2 | 5/21-5/25/84 (5 days) | 0800-1530 |
| 2 - During encapsulation, School not in session | 1 | 7/9-7/12/84 (4 days) | 2400-0800* |
| 3 - After Encapsulation, School not in session | 1 | 7/30-8/3/84 (5 days) | 0800-1530 |
| 4 - After encapsulation, School in session | 1 | 10/1-10/5/84 (5 days) | 0800-1530 |

*Encapsulation carried out 2400-0800.

While school was in session, samples were collected at each site from 8:00 am to 3:30 pm using two types of sampling systems which are described below. When school was not in session during the summer months, similar sampling was done for Periods 2 and 3. However, during Period 2 the time of sampling was from midnight to 8:00 am rather than from 8:00 am to 3:30 pm and for four days rather than five because this was when the encapsulation work took place. A total of 189 air samples (177 plus four mobile pump samples and eight personal samples) were collected on 47 mm Millipore filters during the four periods. The standard sampling rate was approximately 5 liters/min. (Personal samples ran at 2 liters/min.)

## A. Sampling System

The primary air sampling system at each site consisted of two filter holders attached to a single pump, thus providing two side-by-side samples. An extra sample was collected with a single filter system when equipment was available. The double filter system is similar to the single system shown in Figure 6.1, but with two orifices instead of one, and two filter holders. The orifices control the flow through a 47 mm filter holder. The orifices were drilled No. 64 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.

## B. Field Operations

Air sampling was started simultaneously at each school following the protocol in Appendix B-1.

Each field team member was given a hardbound logbook for recording data. Type and operation of air conditioners, room ventilation and occupancy, floor covering, and method and frequency of cleaning were recorded in addition to the data specified in the sampling protocol (Appendix B-1).

Sites were inspected regularly to collect required information and to make sure that they remained operational during the sampling period. Corrective action, such as replugging in power cords, resetting timers, replacing malfunctioning equipment, cleaning orifices, and reconnecting hoses was taken as needed, and recorded in the log book. If filters were damaged early in the sampling period, new filters were installed and the unit was re-started.

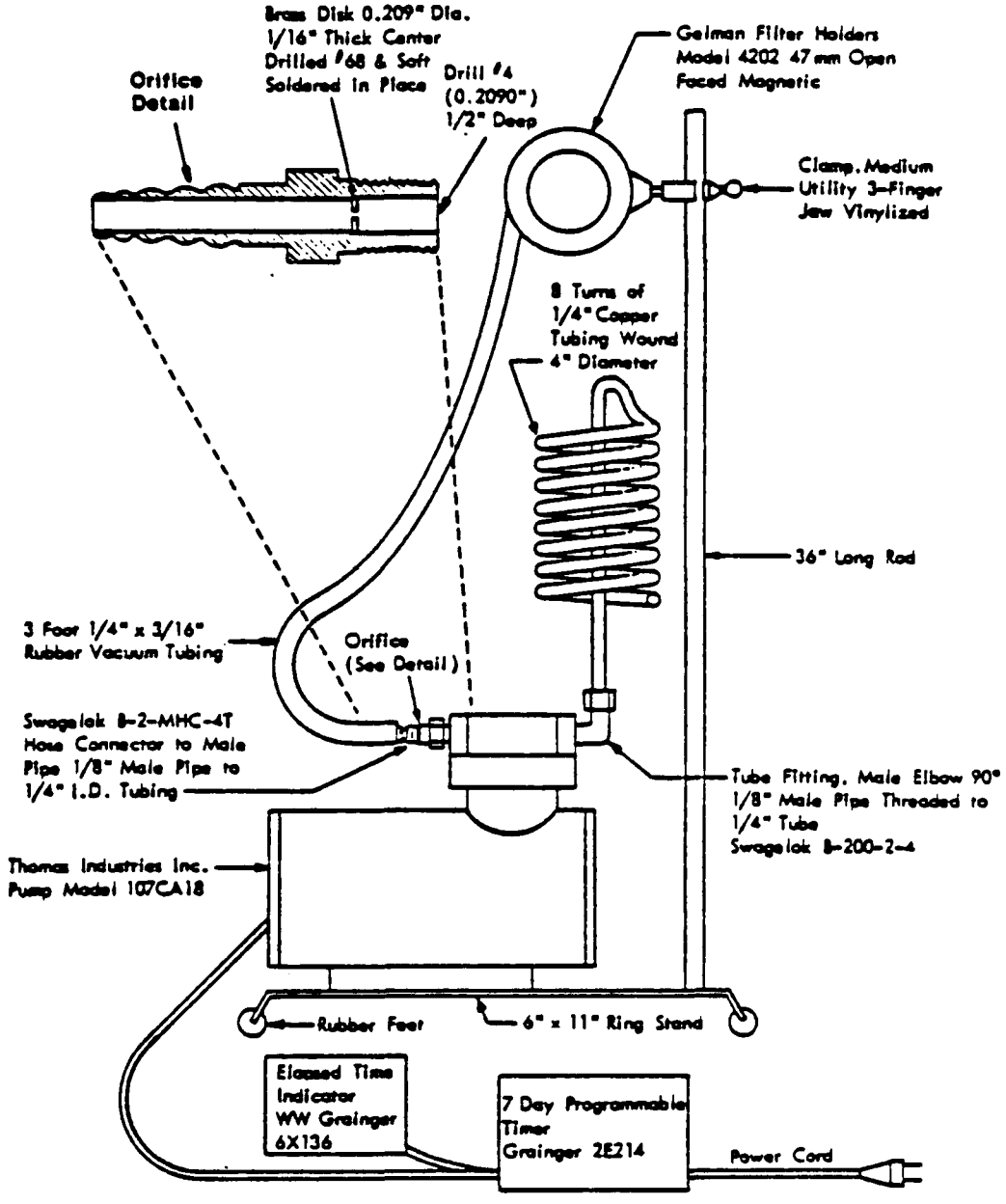


Figure 6.1. Air sampling system.

### C. Sample Handling

The air samples were handled according to established 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

Bulk samples were collected during Period 1 only. A total of 30 samples were collected from two schools. Samples were collected from randomly selected locations at a site. At School 1, samples were collected at 18 locations. Side-by-side samples were taken at four of the locations to provide for duplicate analysis giving a total of 22 samples. At School 2, there were seven locations and one side-by-side sample giving a total of eight samples.

### A. Sample Selection

Sampling locations were selected using a random sampling scheme. The locations of the bulk-sampling points were recorded in the field logbook.

### 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 the laboratory. 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 the laboratory. The quality control representative identified the duplicates and selected the samples to be analyzed according to the QA Plan. 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. Samples were hand-carried from the field to the appropriate analyzing laboratories along with documentation to ensure that all samples were correctly identified and accounted for.

## SECTION 7

## SAMPLE ANALYSIS

Two types of analyses were performed. Air samples collected on Millipore filters were analyzed by TEM. Bulk samples were analyzed by polarized light microscopy (PLM). TEM analyses were done by BCL and PLM analyses were done by MRI. External quality assurance was provided by EMS Laboratories for TEM and by Environmental Health Laboratory for PLM.

### I. AIR SAMPLES

A total of 139 filters were analyzed by TEM at BCL. Twenty-six (26) were analyzed in duplicate and 23 in replicate giving a total of 188 analyses. A computer listing of the results appears in Appendix C-1.

### A. Methods

The protocol for TEM is given in Appendix B-4. The samples were coded so that the analyst did not know where the samples were taken or which samples were field blanks. The large amount of debris (non-asbestos organic matter) collected on many of the filters made the low temperature ashing procedure a necessity. To maintain comparability between samples, all samples were ashed. After ashing, the residue containing the asbestos fibers was resuspended in 100 mil 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 mil, 20 mil, and 70 mil 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 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. A fiber was defined as a particle with an aspect ratio (length: width) of 3:1 or greater and having parallel sides. The fibers observed were identified as chrysotile, amphibole, or other. In this study only chrysotile fibers were found.

The length and width of the chrysotile 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$\mu$m 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$\mu$m 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. 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$\mu$m long by 0.025$\mu$m in diameter. Since the chrysotile fiber becomes cylindrical by rolling up the silica/brucite sheet, 0.025$\mu$m is about the minimum diameter possible for structural identity. The minimum diameter detected during this study was 0.025$\mu$m. The maximum fiber size would be one that overlaps the 90$\mu$m grid opening. The largest bundle observed during this study was 2$\mu$m in diameter.

The smallest non-zero value for this analysis is one fiber in 10 grid openings. 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 corresponds to $4 \times 10^3$ fibers per filters. If the one fiber were of average dimensions (1$\mu$m long x 0.05$\mu$m in diameter), the mass would be $2 \times 10^{-11}$ g per filter. Since approximately 10 $m^3$ of air was collected, the smallest non-zero mass concentration is 0.002 $ng/m^3$.

## B. Discussion

There were 27 samples that contained what appeared to be paint on the filter. The paint pigment is not oxidized or vaporized during the low temperature ashing procedure, thus there are additional particles of debris added to the sample preparation. The samples containing paint were impossible to analyze for asbestos fibers with the normal dilution procedure. Therefore, it was necessary to increase the amount of dilution. Dilution factors for the normal procedure range from 5.72 (70 mil aliquot) to 40 (10 ml aliquot). Dilution factors for samples containing paint range from 40 to 1200. Individual fibers detected at the greater dilution have a greater effect on the estimated asbestos concentration.

In general, the chrysotile fibers detected in the paint-containing samples are longer than the chrysotile fibers observed in the other samples.

Fiber bundles and fiber clusters required special attention. A bundle is defined as a group of fibers bound together that makes the determination of its constituents difficult. Often it was possible to identify one end of a fiber, but it was not always possible to identify positively all the other bundle

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, asbestos air levels are under-estimated for samples with bundles and clusters. There were 36 five-day samples that had some bundles or clusters (Table 7.1). Three of these were outdoor control samples and nine were indoor samples at sites without asbestos-containing material (indoor controls). The remaining 24 were samples from sites were 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 follows the low temperature ashing may tend to break up the fiber bundles and clusters. The primary purpose of sonification is 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.

## C. Quality Assurance

Additional TEM analyzes were done to ensure that the quality of the data is sufficient to support the conclusions of the study. Blank filters (filters which were not used to collect air samples) were analyzed by TEM to check for any asbestos contamination that might occur during manufacture of the filter, during handling in the field, or during the TEM analysis procedure itself. Over half of the air samples collected in the field were analyzed twice, either by a second analyst using the same grid preparation (duplicate analysis), by a second analyst using a second preparation (replicate analysis) or by a second laboratory (external QA). The replicate, duplicate and external QA analyses, as well as detecting gross anomalies, provide information on

Table 7.1. The Number of Chrysotile Bundles/Clusters Observed on the Filters But Not Used in Mass Calculations

| Sampling Period | Site Type | Filter ID (total number of bundles/clusters)* |
|---|---|---|
| Before encapsulation | Unpainted Asbestos | WD29(0+1), WD30(2), WD33(3), WD36(1), WD38(0+3), WD47(1), WD48(3+1), WD49(3), WD54(1), WD57(4+6), WD59(1), WD62(3), WD63(4) |
| | Painted Asbestos | WD31(4), WD43(1), WD56(0+2), WD67(1), WD68(8+9), WD69(3), WD70(1+1), WD71(2+10) |
| | Non-Asbestos | WD40(2), WD60(1+5) |
| During encapsulation | Unpainted Asbestos | WG31(2), WG32(2), WG35(0+1), WG37(1) |
| | Inside Barrier | WG50(1+3), WG54(2), WG61(2), WG65(3), WG69(1), WG70(1) |
| | Mobile Pump | WG24(2), WG27(3) |
| | Personal Pump | WG2(5), WG11(1) |
| Immediately after encapsulation | Unpainted Asbestos | WMG19(2+1), WMG20(1) WMG23(1), WMG31(0+2), WMG40(2) |
| | Painted Asbestos | WMG35(1) |
| After school resumed | Unpainted Asbestos | WCD2(6+4), WCD5(3), WCD8(2+3), WCD9(2), WZ26(1), WZ27(2) WZ30(4+4), WZ32(1+4), WZ36(3+2), WZ38(5), WZ43(2), WZ44(0+2), WZ45(2+2), WZ48(0+3+3), WZ37(1) |
| | Painted Asbestos | WZ34(1), WZ35(1), WZ41(1+1), WZ42(3+3) |
| | Non-Asbestos | WCD3(6), WCD4(1), WZ39(2), WZ40(1) |

* Two numbers after a filter ID indicates bundles/clusters found on duplicate or replicate analyses of the same filter.

sources of variability that contribute to the overall variability of TEM measurements.

### 1. Blanks

Two types of blanks were analyzed: Millipore filters which were never taken into the field (laboratory blanks), and Millipore filters that were taken into the field and handled exactly the same as the rest of the filters except that they were never used for air sampling (field blanks). There was field blank for each site and sampling period (73 total). To the analyst, the blanks were indistinguishable from the rest of the filters.

Six laboratory blanks and eight field blanks were analyzed by TEM. These were chosen at random from the available blanks. Since no air was drawn through the blank filters the results are expressed as fibers per filter, or nanograms per filter, rather than per cubic meter of air (Appendix C-2). The average mass concentration is 0.28 ng/filter for the laboratory blanks and 0.33 ng/filter for the field blanks. If these masses had been observed in samples of 10 cubic meters of air (the average volume used in the study) the mass concentrations would be 0.028 $ng/m^3$ and 0.033 $ng/m^3$ for laboratory blanks and field blanks respectively. These values are very small and indicate that sample contamination was not a problem. Since the study data are reported to only one decimal place, any adjustment based on the blanks (e.g., subtracting their mass concentrations from the estimated mass concentration at a site) would have no appreciable effect on either the reported values, or on the statistical analyses described in Section 8. Therefore no correction was made.

### 2. Duplicate, Replicate and External QA Analyses

Of the 139 filters analyzed by TEM, 26 were selected for duplicate, 23 were selected for replicate, and 30 were chosen for external QA analysis. Results are given in Appendix C-2.

For each pair of duplicate, replicate, and external QA analyses, the coefficient of variation (CV), which is the standard deviation expressed as a percentage of the mean, was calculated. A large CV indicates a large difference between the members of the pair. For two samples the CV can range from 0% to 141%.

The largest coefficients of variation are expected for the external QA analyses, since they include all the sources of variability present in the replicate and duplicate analyses plus variability between laboratories. Likewise, the coefficients of variation for replicate analyses which use different preparations are expected to be larger than those for duplicate analyses. The expected ranking is not clearly apparent in Figure 7.1 where the

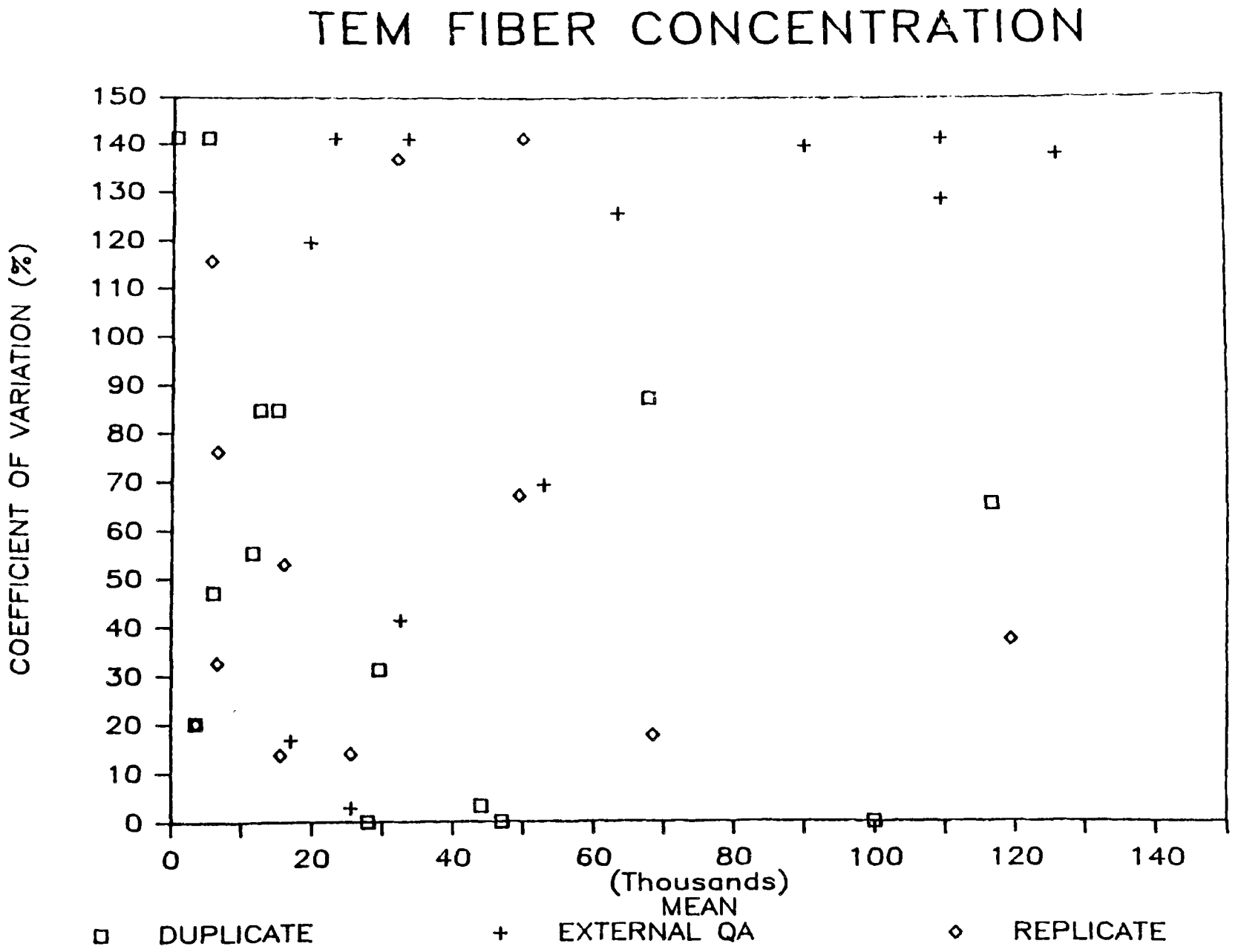


Figure 7.1. Coefficient of variation for duplicate, replicate and external QA analyses plotted against the mean fiber concentration (thousands of fibers/$m^3$) measured by TEM. One outlier with mean 7.6 x $10^8$ fibers/$m^3$ has been excluded.

coefficient of variation for each external QA, replicate and duplicate analysis pair is plotted against the mean fiber concentration of the pair. The external QA analyses do tend to have the largest coefficients of variation (maximum 140%) but they are only slightly higher than the replicates (maximum 126%). Figure 7.2 is the corresponding plot for mass concentrations. The lack of an obvious difference between the three types of analyses indicates that the variability introduced by different preparations and different laboratories is not large relative to the variability associated with other aspects of the TEM measurement. Other potential sources of variability (e.g., sampling error introduced by examining only a very small portion of the entire sample) need to be identified and reduced in order to achieve a significant improvement in precision.

The study was designed with enough samples (sites) to compensate for the expected low precision of a single TEM measurement. Although individual fiber and mass concentrations have low precision, the main conclusions of the study are based on concentrations from many sites. The statistical analyses described in Section 8 identify statistically significant differences between mean concentrations taking variability of individual measurements into account.

## II. BULK SAMPLES

Thirty bulk samples were collected and analyzed for asbestos and other materials by polarized light microscopy (PLM) procedures, and rated for releasability by stereomicroscopic techniques. The thirty samples included four side-by-side pairs. One member of each pair was analyzed by the main laboratory and the second member by an external QA laboratory. Eight samples were analyzed in replicate (two independent preparations from the same sample), and eight samples were analyzed in duplicate (two analysts used the same preparation) giving a total of 46 analyses. (Appendix C-3).

### A. Methods

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

The analyses were carried out with 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 through the stereomicroscope for

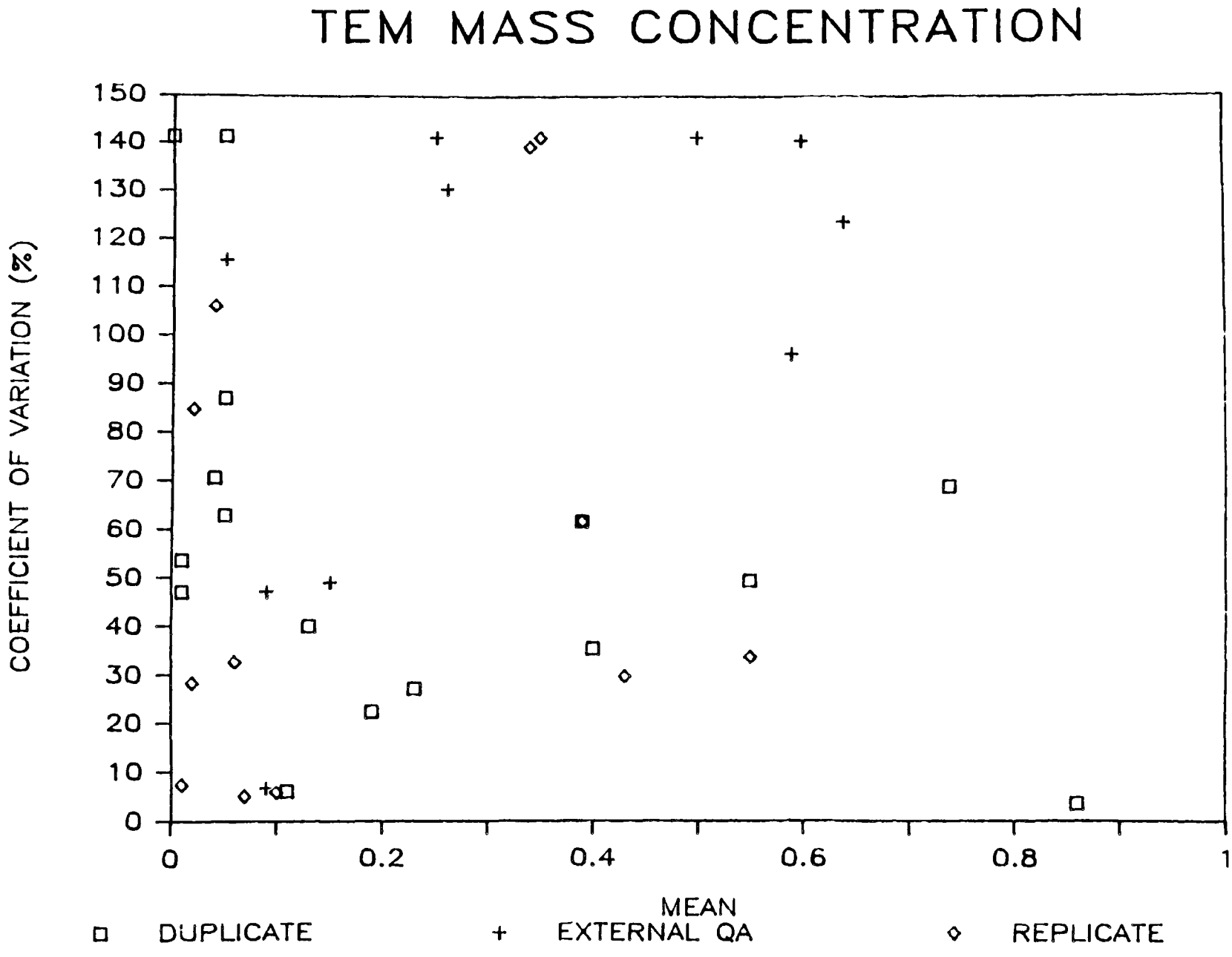


Figure 7.2. Coefficient of variation for duplicate, replicate and external QA analyses plotted against the mean mass concentration (ng/m$^3$) measured by TEM. One outlier with mean 8.740 ng/m$^3$ has been excluded.

layering, homogeneity, and the presence of fibrous material. Identification of large nonfibrous components was usually possible at this point. Subsamples were then mounted onto a clean microscope slide, in liquids with the appropriate index of refraction, for examination through the polarizing microscope.

The PLM procedure consisted of examining the sub-sample 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 fibrous and some of the nonfibrous components were identified on the basis of morphology, sign of elongation, and refractive index/dispersion staining colors.

Volumes of the various materials were estimated as a percentage of the whole sample.

The samples were also rated for the apparent availability of releasable fibers from the bulk material. They were rated on an arbitrary scale of 0 through 9 which was developed during an earlier EPA study (USEPA 1983b). The rating is a subjective determination which 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 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.

## B. Results

The results from the PLM analysis are given in Appendix C-3. The bulk materials were all quite similar. They all contained chrysolite asbestos in a perlite matrix.

## C. Quality Assurance

Of the 30 bulk samples collected and analyzed by PLM, eight were analyzed in duplicate and eight were analyzed in replicate. The eight samples designated for replicate analysis were analyzed by a second analyst without reference to the results of the first. The eight samples designated for duplicate analysis were analyzed by a second analyst using the same PLM slide preparations as the first analyst. Fiber identification is made from the slide preparation. Quantitation of components is made by examining the entire bulk sample under the stereo microscope after the component identification is complete. From each of the four pairs of side-by-side samples, one member was selected for analysis by a second laboratory. The results of percent chrysotile content

and releasability rating for duplicate, replicate, and external quality assurance analysis are presented in Appendix C-4.

The CV's calculated for the percent chrysotile per volume were quite variable and tended to be high, ranging from 0% to 89% (Figure 7.3). Further investigation showed that one analyst was giving results that were higher than a second analyst and the external QA laboratory (Appendix C-4). This discrepancy does not affect the main conclusion that the bulk materials were all quite similar. It does mean, however, that the numerical values should be treated cautiously if comparisons are made with other studies. Reanalysis is recommended if more precise information is needed.

The CV's calculated for the releasability ratings were generally less than those calculated for the percent chrysotile (Figure 7.4). With the exception of one value (54%), the CV's were all less than 50%. This is a reasonable level of precision give the subjective nature of the rating scheme.

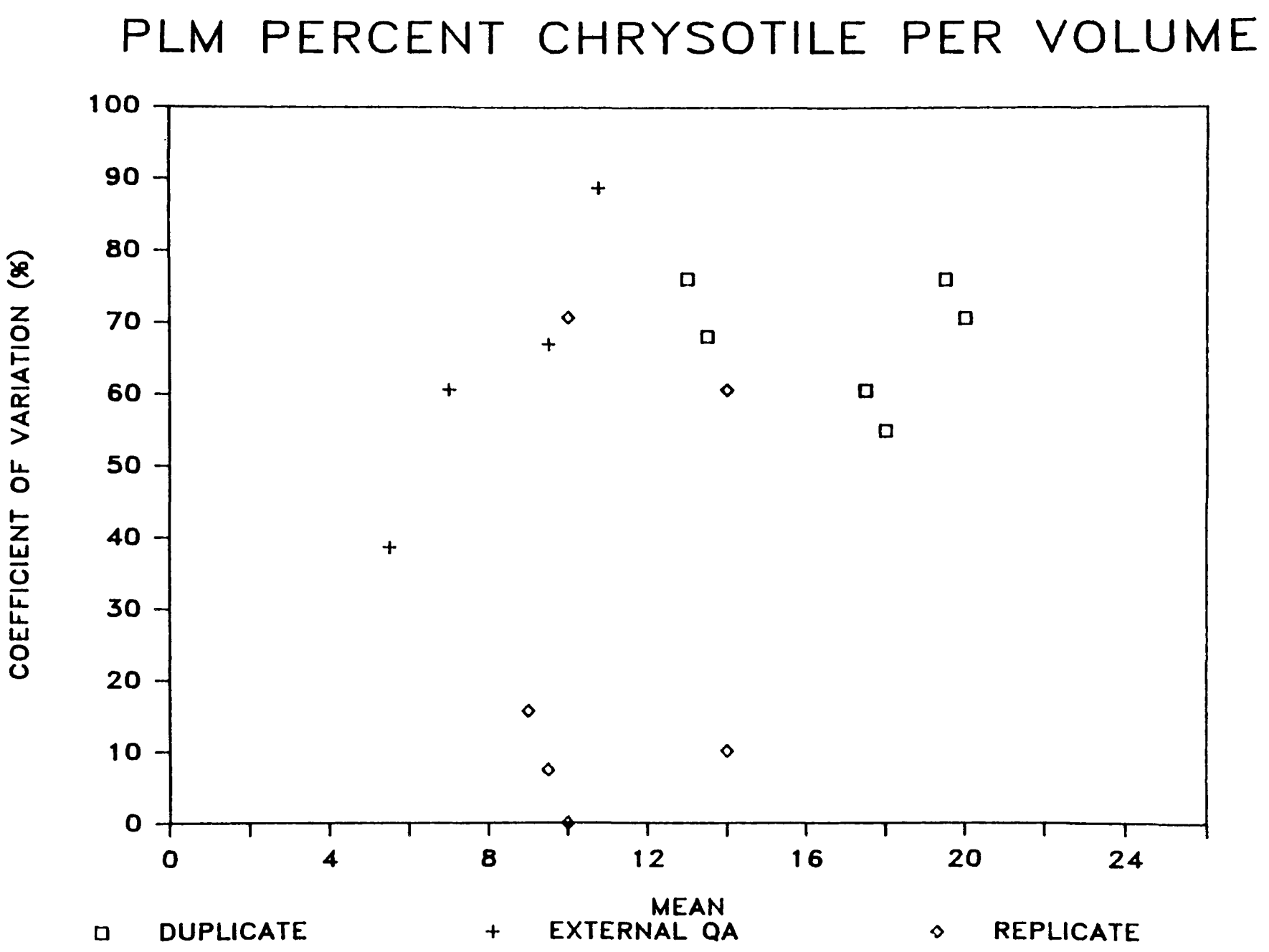


Figure 7.3. Coefficient of variation for duplicate, replicate and external QA analyses plotted against the mean percent chrysotile content in bulk samples measured by PLM.

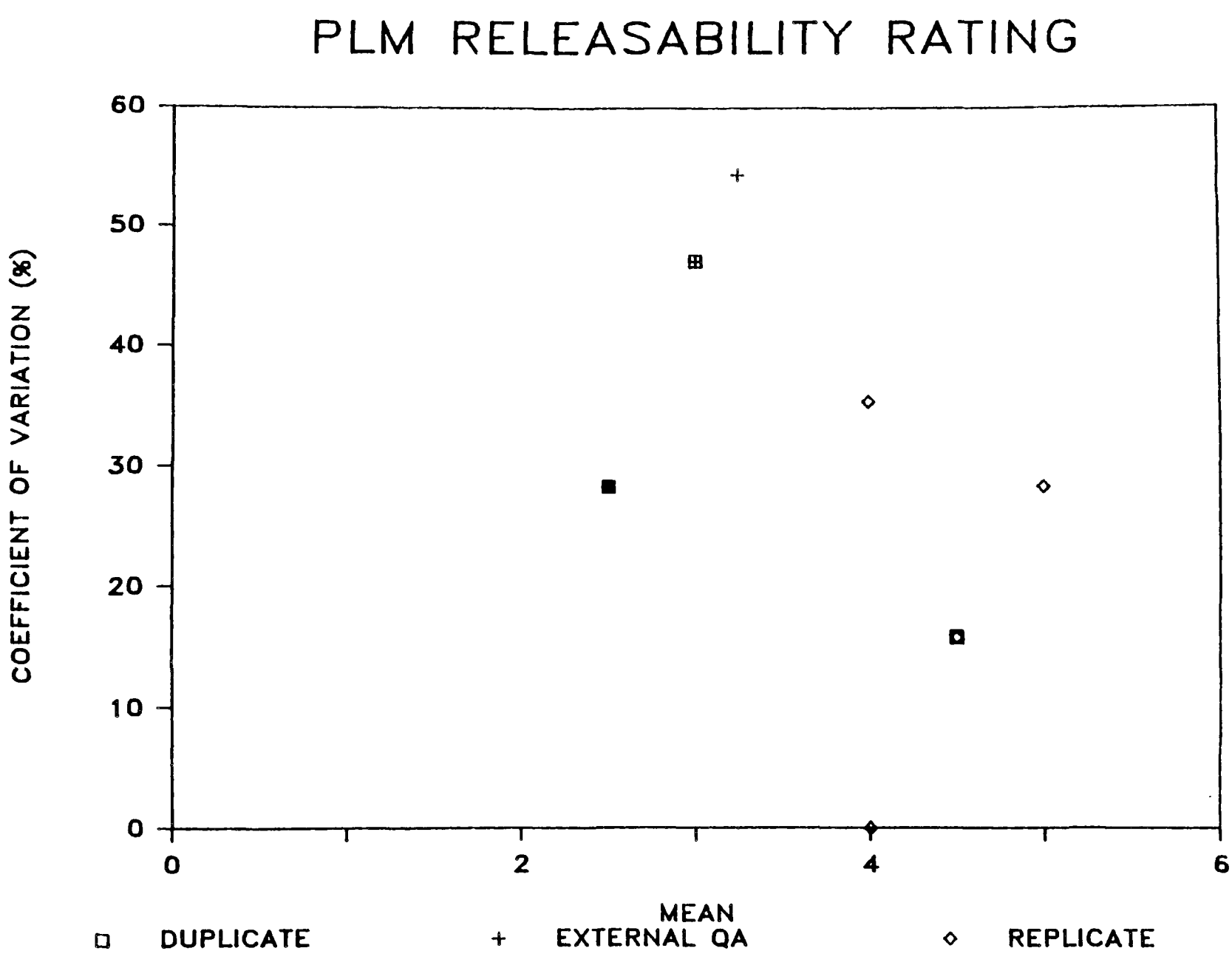


Figure 7.4. Coefficient of variation for duplicate, replicate and external QA analyses plotted against the mean releasability rating for bulk samples.

# SECTION 8

# STATISTICAL ANALYSIS

## I. METHODS

The data were transformed to a log scale before analysis. This was done because the distribution of asbestos air levels is typically skewed to the right. On the original scale a few large values can have a disproportionate influence on the results. On the log scale the effect of the few large values is reduced. The transformation results in standard deviations that are independent of the mean and thereby allows standard statistical tests, such as analysis of variance, to be applied. The transformations used were $\log_e (x + 1)$ and $\log_e(1{,}000x + 1)$ for fiber and mass concentrations respectively. The use of these transformations is equivalent to assuming a lognormal distribution and working with the geometric mean or median instead of the common arithmetic mean.

For each type of indoor site (unpainted asbestos, painted asbestos, non-asbestos) a one-way analysis of variance was used to test whether there were any differences among the four sampling periods. When more than one measurement was available for a particular site and period, a weighted average of the available measurements was used to arrive at a single value. The weights were equivalent to first averaging any duplicate determinations to obtain a single value for a preparation, and then averaging any replicate determinations to obtain a single value for a filter. Values from side-by-side filters were averaged to provide a single value for each location within a site, and finally, values for each location were averaged to obtain a single value for a site. For analysis of variance, the "during" samples for unpainted asbestos were those taken immediately outside the barriers. Samples collected within the work area during painting are reported separately. This was done to achieve consistency with the analysis of the previous abatement efficacy study. The non-parametric Kruskal-Wallis test was also used. This test performs the same function as the analysis of variance but does not assume a particular distribution for the air levels. Agreement between the two tests indicates that the conclusions do not rely on the assumption of an underlying lognormal distribution.

Three air samples were collected at some sites when extra pumps were available. Two samples were collected on side-by-side filters attached to a single pump. The third sample was collected with a pump placed on the other side of the room. If airborne asbestos concentrations vary from location to location within a room (spatial variability), the two side-by-side samples will be more similar to each other than to the sample on the other side of the room. The magnitude of the spatial variability can be quantified by decomposing the total variability into the component

due to spatial variability (location to location within a site) and the component due to collection and analysis of the sample. This was done by fitting the model:

$$y_{ijk} = \mu + \alpha_i + \beta_{j(i)} + \epsilon_{ijk}$$

where $y_{ijk}$ is the log transformed fiber or mass concentration measured at site i, location j, on filter k. For example $y_{5,1,1}$ and $y_{5,1,2}$ represent concentrations at site 5, location 1 using side-by-side filters 1 and 2, whereas $y_{5,2,1}$ represents the concentration measured by filter 1 on the other side of the room (location 2). The overall mean is $\mu$ and $\alpha_i$ is the fixed deviation from the mean associated with site i. $\beta_{j(i)}$ is a random deviation associated with sampling location j within site i. $\beta_{j(i)}$ is assumed to come from a normal distribution with mean 0 and variance $\sigma^2_L$. Thus, $\sigma^2_L$ is a measure of spatial variability within a site. $\epsilon_{ijk}$ is a random deviation associated with a given filter k at location j within site i. $\epsilon_{ijk}$ is assumed to come from a normal distribution with mean 0 and variance $\sigma^2_E$. The error variance, $\sigma^2_E$, describes the variability associated with different samples taken simultaneously at a single location and therefore includes variability associated with the collection and analysis of the sample.

The model was fitted using MIVQUE(O) Variance Component Estimation Procedure of SAS (Statistical Analysis System, SAS Institute Inc.) and the magnitude of the spatial variability $\sigma^2_L$ was compared to the magnitude of the total variance, $\sigma^2_L + \sigma^2_E$.

Information on the bulk material was tabulated. However, since the material is very similar throughout sites within a school, no formal statistical analyses were carried out.

## II. RESULTS

Data listings are given in Appendix D-1.

### A. Air Samples

With the exception of measurements taken during actual painting, airborne asbestos levels were generally low at all sites. (Table 8.1 and Appendix D-2). The highest levels were observed before painting and the lowest immediately after painting. Very few fibers were found at the outdoor site during any of the sampling periods. Figures 8.1 and 8.2 show the distribution of values for fiber and mass concentrations respectively. The maximum and minimum concentrations during each period at each type of site are indicated by the upper and lower extremes of the box plots. The shaded area contains fifty percent of the sites (25th percentile to the 75th percentile) and the horizontal bar marks the

Table 8.1. Geometric mean of fiber and mass concentrations for each type of site before, during and after encapsulation of the asbestos - containing material with latex paint. The "during" samples for unpainted sites were collected immediately outside the plastic barriers separating the work area from the rest of the school.

| | PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BEFORE ENCAPSULATION | | DURING ENCAPSULATION | | IMMEDIATELY AFTER ENCAPSULATION | | AFTER SCHOOL RESUMED | |
| | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
| CODE | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN | GEOMETRIC MEAN |
| UNPAINTED ASBESTOS | 1423.6 | 6.7 | 117.2 | 0.6 | 13.7 | 0.1 | 248.1 | 1.2 |
| PAINTED ASBESTOS | 622.9 | 2.7 | . | . | 0.8 | 0.0 | 187.2 | 0.8 |
| NON-ASBESTOS | 250.6 | 1.2 | 0.5 | 0.0 | 9.3 | 0.0 | 30.7 | 0.2 |
| INSIDE BARRIER | . | . | 70.0 | 0.8 | . | . | . | . |
| OUTDOOR | 3.5 | 0.0 | 0.0 | 0.0 | 6.5 | 0.0 | 2.8 | 0.0 |

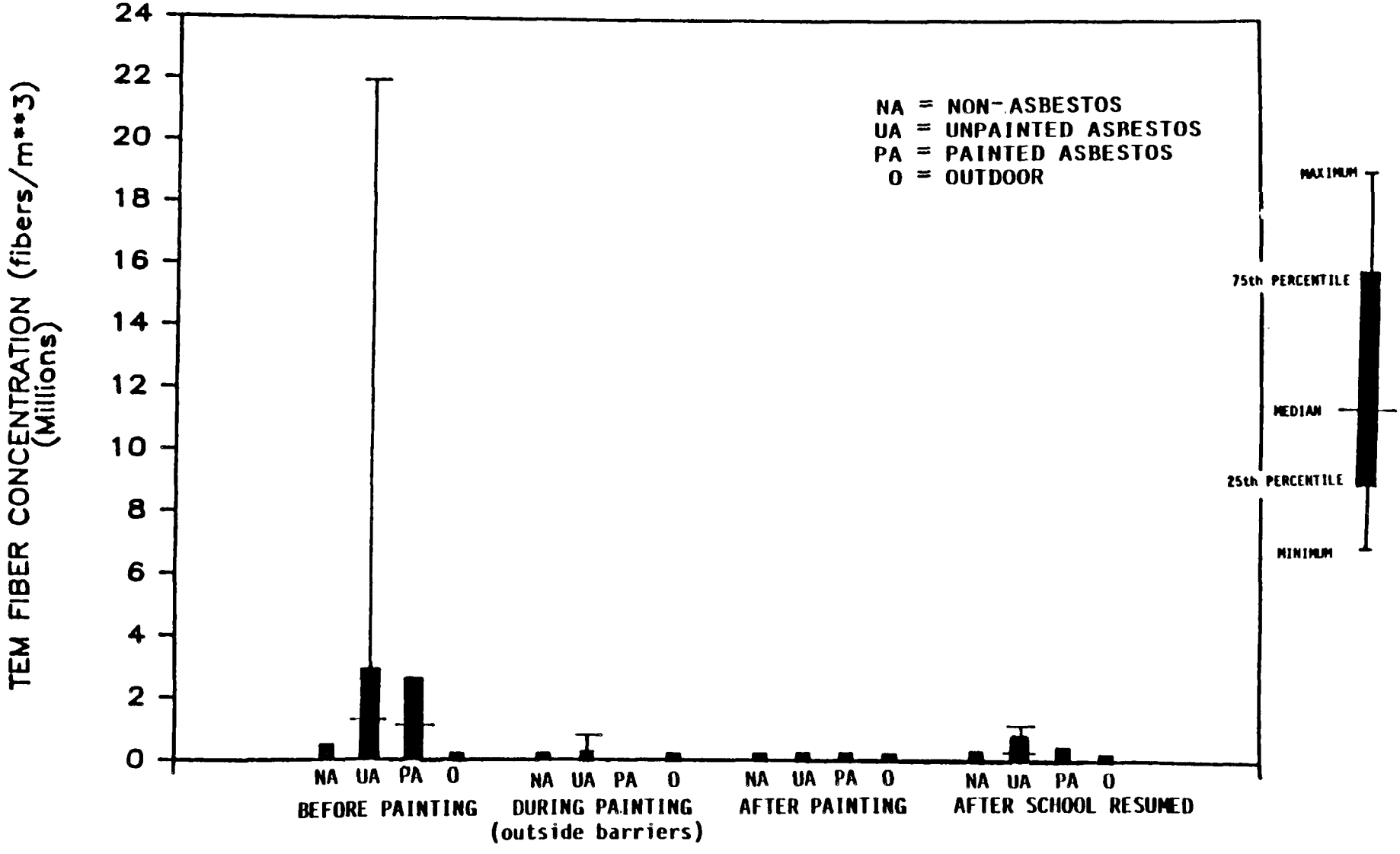


Figure 8.1. Fiber concentration (fibers/$m^3$) at each site and for each sampling period. During encapsulation the unpainted asbestos sites were located immediately outside the barriers separating the work area from the rest of the school. See Appendix E, Table E-1, for the actual data values.

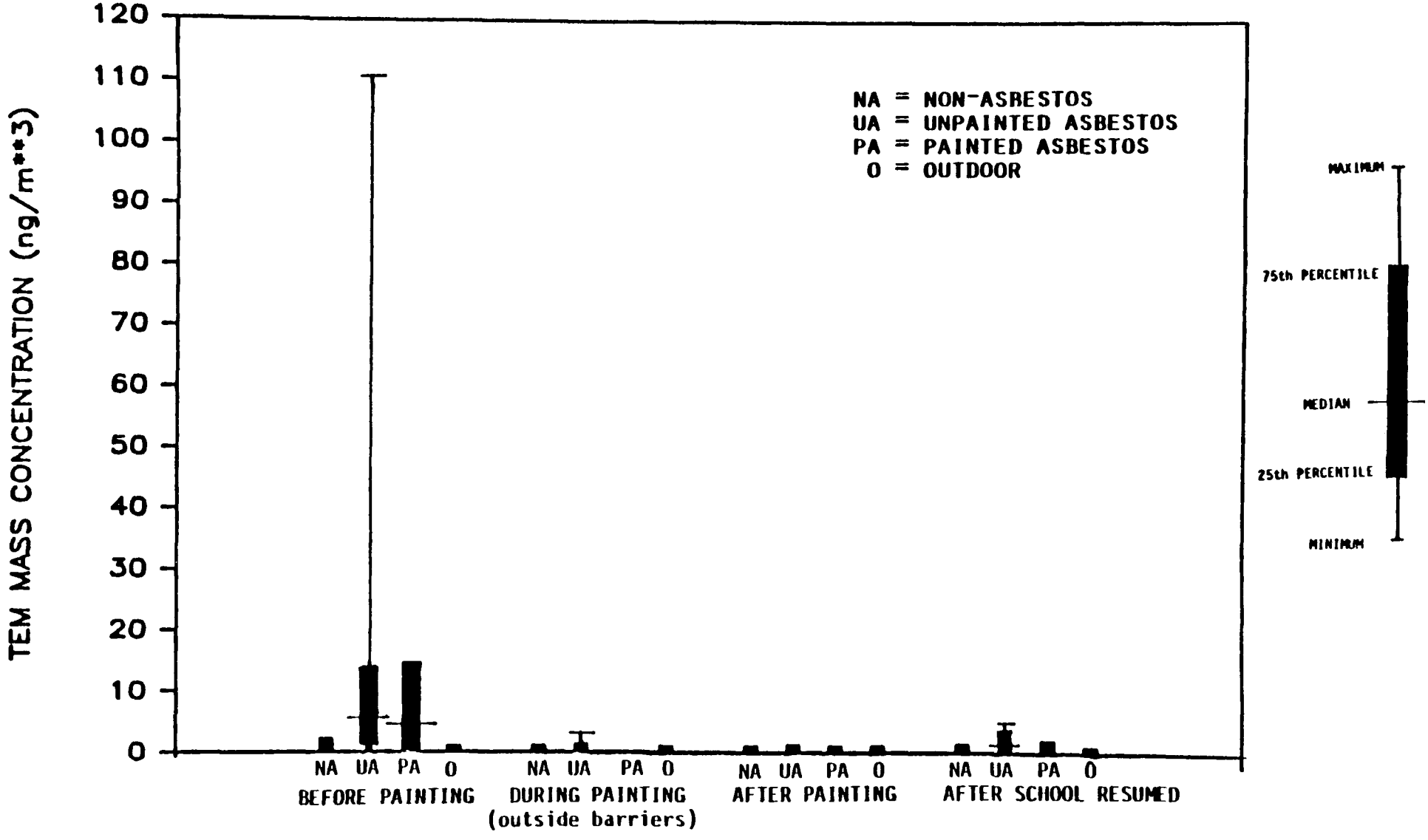


Figure 8.2. Mass concentration (ng/m$^3$) at each site and for each sampling period. During encapsulation the unpainted asbestos sites were located immediately outside the barriers separating the work area from the rest of the school. See Appendix E, Table E-1, for the actual data values.

median. The data used to construct the figures are listed in Appendix E, Table E-1. The figures do not include measurements taken in the work area during the encapsulation.

Both the analysis of variance and the Kruskal-Wallis test showed that there were statistically significant changes from one sampling period to another at the unpainted asbestos sites ($p = .0001$). Pairwise comparisons using Bonferroni's method (Miller 1981) showed that airborne asbestos levels before encapsulation were significantly higher than those after encapsulation, and that airborne asbestos levels after school resumed were significantly higher (although still very low) than those immediately after encapsulation. Airborne asbestos levels after school resumed were still significantly lower than those before encapsulation.

These results suggest that the painting operation, with its associated thorough cleaning resulted in a reduction in airborne asbestos levels. The slight, but statistically significant, increase in levels after school resumed compared to immediately after encapsulation could reflect the increased activity in the building, or might imply that the effect of the encapsulant is only temporary. Further sampling as needed to answer this question.

There was no statistically significant change from period to period in airborne asbestos levels at sites that had been painted prior to the study although the values did follow a trend similar to the unpainted sites. The non-asbestos sites did show a significant decrease in mass concentration between the first and second sampling periods ($p = .0098$ and $p = .032$ for analysis of variance and Kruskal-Wallis tests, respectively). This decrease was not evident for the corresponding fiber concentrations suggesting the possibility of a change in fiber size distribution. Results for the non-asbestos sites must be treated cautiously since these sites were in the few unusual locations (storerooms, etc.) that did not contain asbestos material.

Average levels inside the painting area ("inside barrier") over the entire painting period were higher than those outside the work area but were still quite low ($< 10$ ng/m$^3$) (Table 8.1 and Appendix D.2). These levels represent an average over a five-day period which includes short periods of painting plus periods of inactivity. Samples taken with mobile pumps during the actual painting gave much higher readings (up to almost 9,000 ng/m$^3$) (Table 8.2). These samples were badly contaminated with paint. Silica particles obscured fibers and made sample analysis difficult. Therefore levels are probably underestimated. The personal pumps worn by two of the painters showed very low levels of airborne asbestos in one case (0.0 ng/m$^3$) and high levels in the other (up to 13,000 ng/m$^3$) (Table 8.3). Although the data are variable they indicate that there is a substantial risk of exposure during painting. The reason for the difference between the two

Table 8.2. Fiber and mass concentrations during painting. The samples were collected by moving pumps from room to room as the painting progressed.

MOBILE PUMPS

| | | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
|---|---|---|---|
| | | TEM | TEM |
| SITE | ID | | |
| PRIMARY HORIZONTAL SPRAY | WG-24 | 47000.0 | 390.0 |
| | WG-25 | 63000.0 | 380.0 |
| SECONDARY VERTICAL SPRAY | WG-26 | 4000.0 | 40.0 |
| | WG-27 | 757000.0 | 8740.0 |

Table 8.3. Fiber and mass concentrations obtained from personal pumps worn by two of the painters.

PERSONAL PUMPS

| | | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
|---|---|---|---|
| | | TEM | TEM |
| CODE | ID | | |
| PERSON 1 | WG-12 | 0.0 | 0.0 |
| | WG-22 | 0.0 | 0.0 |
| PERSON 2 | WG-1 | 600000.0 | 13000.0 |
| | WG-11 | 440000.0 | 2300.0 |
| | WG-2 | 300000.0 | 1000.0 |
| | WG-23 | 180000.0 | 1700.0 |

painters is unknown. The personal pumps were checked and found to be working properly. The field crew did note, however, that the first painter, being tall, rarely used the scaffolding and therefore was not as close to the material as the other painters. This painter had the very low levels.

The observations are consistent with the results of an experimental study to evaluate encapsulants (Mirick et al. 1982). During application of the encapsulants, airborne asbestos levels of 2,500 ng/m$^3$ to 4,500 ng/m$^3$ were measured. These data underscore the need for appropriate worker protection during encapsulation operations.

Airborne asbestos levels at a second school where the material had been painted three years prior to the study were higher than those at most sites in the first school (Table 8.4). Without knowing what the levels were prior to encapsulation, it is not possible to say whether these levels represent an improvement over the situation prior to encapsulation or whether the effectiveness of the encapsulant has diminished over time. The outdoor sample at this school was damaged and therefore unavailable for analysis.

Tables 8.5 and 8.6 show fiber and mass concentrations respectively at sites where there were two sampling locations. At these sites one double-headed pump was placed at one side of the room and one single-headed pump was placed at the opposite side of the room. This design provides a comparison between two measurements taken side-by-side (with the double-headed pump) and one measurement taken at the other side of the room. If there is a lot of variability from one location in the room to another, then one would expect the two side-by-side measurements to be much more similar to each other than to the third measurement taken across the room.

Only limited data are available because budget constraints prevented analysis of all of the available samples. Also, the airborne asbestos levels were generally low and the restricted range does not provide a good comparison of within-and between-location variability. Therefore the results must be regarded as tentative. Even when there was only one pump at a site, side-by-side measurements were used in the analysis to give a better estimate of $\sigma^2_E$. For fiber concentration, the estimated spatial variability ($\sigma^2_L$) is 4.1 compared to an estimated error variance ($\sigma^2_E$) of 4.3. For mass concentration the estimates are 0.7 and 2.6. Spatial variability accounts for 49% of the total variability in fiber concentration and for 22% of the total variability in mass concentration.

Estimates of $\sigma^2_L$ and $\sigma^2_E$ are helpful in designing future studies. For example, it two samples can be collected per site, then the precision of the estimate of airborne asbestos levels will

Table 8.4. Fiber and mass concentrations at school 2 where the material had been encapsulated 3 years ago.

SCHOOL 2

| | | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
|---|---|---|---|
| | | TEM | TEM |
| TYPE | SITE | | |
| PAINTED ASBESTOS | 1 | 938.0 | 8.7 |
| | 2 | 6640.0 | 32.8 |
| | 3 | 6840.0 | 29.7 |
| | 4 | 6990.0 | 39.7 |

Table 8.5. Fiber concentrations measured in two locations within a single site. At the first location two side-by-side samples were collected but only some were analyzed because of budget constraints.

| | LOCATION WITHIN SITE | | |
|---|---|---|---|
| | SIDE-BY-SIDE | | OTHER SIDE Of Room |
| | FILTER NUMBER | | |
| | 1 | 2 | |
| | FIBERS/M**3-(THOUSANDS) | FIBERS/M**3-(THOUSANDS) | FIBERS/M**3-(THOUSANDS) |
| | ******** | ******** | ******** |
| SITE | | | |
| 14 | 190.0 | 667.0 | 2160.0 |
| 15 | 1810.0 | . | 4140.0 |
| 16 | 3520.0 | . | 1890.0 |
| 31 | 1.0 | . | 5.0 |
| 33 | 3.5 | . | 4.0 |
| 34 | 32.0 | . | 5.0 |
| 35 | 15.0 | . | 0.0 |
| 36 | 15.0 | . | 68.5 |
| 38 | 3.0 | 47.0 | 9.0 |
| 39 | 0.5 | . | 26.0 |
| 41 | 164.0 | . | 1610.0 |
| 43 | 408.0 | 507.0 | 17.0 |
| 45 | 167.0 | 1160.0 | 278.0 |
| 49 | 110.0 | 457.0 | 1300.0 |

Table 8.6. Mass concentrations measured in two locations within a single site. At the first location two side-by-side samples were collected but only some were analyzed because of budget constraints.

| | LOCATION WITHIN SITE | | |
|---|---|---|---|
| | SIDE-BY-SIDE | | OTHER SIDE Of Room |
| | FILTER NUMBER | | |
| | 1 | 2 | |
| | NG/M**3 | NG/M**3 | NG/M**3 |
| | ******** | ******** | ******** |
| SITE | | | |
| 14 | 1.1 | 2.9 | 9.4 |
| 15 | 7.1 | . | 24.4 |
| 16 | 15.1 | . | 8.8 |
| 31 | 0.0 | . | 0.0 |
| 33 | 0.0 | . | 0.0 |
| 34 | 0.3 | . | 0.1 |
| 35 | 0.1 | . | 0.0 |
| 36 | 0.1 | . | 0.4 |
| 38 | 0.0 | 0.2 | 0.1 |
| 39 | 0.0 | . | 0.1 |
| 41 | 0.7 | . | 6.7 |
| 43 | 2.0 | 2.9 | 0.1 |
| 45 | 0.9 | 5.1 | 1.4 |
| 49 | 0.5 | 3.1 | 5.6 |

depend on whether two side-by-side samples are collected, or whether two samples are collected from different parts of the room. Based on these results, two side-by-side samples will provide an estimate of log fiber concentration with a variance of 4.1 + 4.3/2 = 6.3 (a reduction of 25% compared to the variance of an estimate based on just one sample), and an estimate of log mass concentration with a variance 0.7 + 2.6/2 = 2.0 (a reduction of 39%). If two samples are collected from different parts of the room the variances will be even smaller ((4.1 + 4.3)/2 = 4.2 and (0.7 + 2.6)/2 = 1.7 respectively). Thus, collecting samples from two locations provides additional precision. This has to be weighed, however, against the cost of extra equipment and effort. More data are required before any confidence can be put in the actual numerical values. Nevertheless, these results indicate that variability from location to location within a site should be considered when determining the number of samples needed to achieve a particular objective. If it is important to estimate the airborne asbestos level at a particular site, samples should be collected at more than one location within the site.

## B. Bulk Samples

Bulk samples were analyzed to characterize the asbestos-containing material and allow comparisons with future studies. The mean asbestos content (percent chrysotile) and mean releasability rating of bulk samples from each school is given in Table 8.7. The mean is a weighted average of all sites sampled within the school with each side-by-side sample receiving half the weight of a single sample. Asbestos content and releasability were quite low at both schools (<12% and <3.5 respectively) and did not vary much from site to site within a school (coefficient of variation <45% and <33% respectively).

Table 8.7. Mean asbestos content (percent chrysotile) and mean releasability of bulk samples collected from each school. The means are weighted averages of all sites within a school with side-by-side samples receiving half the weight of other samples.

| | CHRYSOTILE % | | RELEASABILITY | |
|---|---|---|---|---|
| | MEAN | STD | MEAN | STD |
| SCHOOL | | | | |
| 1 | 11.88 | 5.34 | 3.36 | 1.11 |
| 2 | 7.13 | 2.59 | 2.13 | 0.35 |

## REFERENCES


Atkinson G, Chesson J, Price B, Barkan D, Ogden J, Brantley G, Going J. 1983. Midwest Research Institute. Releasability of asbestos containing materials as an indicator of indoor airborne asbestos exposure. Draft Report. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68-01-5915.

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Mirick W, Schmidt EW, Melton CW, Anderson SJ, Nowacki LJ, Clark R. 1982. Evaluation of encapsulants for sprayed-on asbestos-containing materials in buildings. Final Report. Cincinnati, OH: Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency. Contract 68-03-2552 (T2005).

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USEPA. 1983b. U.S. Environmental Protection Agency. Office of Toxic Substances. Airborne asbestos levels in schools. Washington, D.C. EPA 560/5-83-003.

USEPA. 1985a. U.S. Environmental Protection Agency, Office of Toxic Substances. Guidance for controlling asbestos-containing materials in buildings. Washington, D.C. EPA 560/5-85-024.

USEPA. 1985b. U.S. Environmental Protection Agency, Office of Toxic Substances. Evaluation of asbestos abatement techniques; Phase 1: Removal. Washington, D.C. EPA 560/5-85-019.

# APPENDIX A

## EXCERPTS FROM QUALITY ASSURANCE PLAN

## APPENDIX A

## EXCERPTS FROM QUALITY ASSURANCE PLAN

The sections marked with a * are reproduced in this appendix.

Note that the QA plan was written to allow for analysis of air samples by both Phase Contrast Microscopy (PCM) and TEM. Because of budget constraints, only TEM analyses were carried out.

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## 16.0 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 analyses are completed (TEM, PCM). The same procedure shall be used for bulk samples for Polarized Light Microscopy (PLM). 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). PCM 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. Releasability measurements shall be performed according to the protocol in Appendix A. In all cases any deviations from, or elaborations of, the specified protocols shall be carefully documented.

### 16.1 Field Blanks

From the 17 field blanks per sampling period in School 1 (1 per site), 4 shall be randomly selected by MRI's QA monitor for chemical analysis for contamination check. These 4 filters shall consist of one filter from each type of site (i.e., unpainted asbestos-containing, painted asbestos-containing, non-asbestos

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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

containing, outdoors). From the 5 field blanks from sampling period #1 in School 2 (1 per site), 2 shall be randomly selected for contamination check. One filter shall be selected from each type of site (i.e., painted asbestos-containing, outdoor).

## 16.2 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 both methods: transmission electron microscopy (TEM) 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. For each sampling period, the filters shall be selected as follows:

* For TEM analysis (School 1)
  - 1 from non-asbestos containing rooms
  - 1 from painted asbestos containing rooms
  - 4 from unpainted asbestos containing rooms
  - 1 from outdoor
* For PCM analysis (School 1)
  - 2 from non-asbestos containing room
  - 2 from painted asbestos containing rooms

- 8 from unpainted asbestos containing rooms
- 2 from outdoor

*For TEM analysis (School 2, sampling period #1 only)

- 2 from painted asbestos containing rooms

*For PCM analysis (School 2, sampling period #1 only)

- 2 from painted asbestos containing rooms.

No field blanks shall be analyzed by the QA laboratory.

## 16.3 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 analysis 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 each sampling period, filters shall be randomly selected in the same fashion for duplicate and replicate analyses, for both methods (TEM and PCM) as follows:

*For TEM analysis (school 1)

- 1 from non-asbestos free rooms
- 1 from painted asbestos containing rooms
- 4 from unpainted asbestos containing rooms
- 1 from outdoor

*For PCM analysis (school 1)

- 2 from non-asbestos containing rooms
- 2 from painted asbestos containing rooms
- 8 from unpainted asbestos containing rooms
- 2 from outdoor

*For TEM analysis (School 2, sampling period #1 only)

- 2 from painted asbestos containing rooms
- 1 from outdoor

*For PCM analysis (school 2, sampling period #1 only)

- 2 from painted asbestos containing rooms
- 1 from outdoor

## 16.4 Laboratory Blanks

As a mean 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 for each sampling period.

Tables 3 and 4 summarize the sample selection procedures for external QA, replicate and duplicate analyses for schools 1 and 2, respectively.

## 16.5 Bulk Sample QA Analysis

The bulk sampling scheme is presented in Table 2 of Section No. 6.0. A total of 30 bulk samples (22 from school 1, 8 from school 2) shall be collected at asbestos containing sites. All bulk samples will be analyzed using PLM techniques.

Quality assurance analysis of 4 bulk samples shall be done by a laboratory other than MRI. These 4 samples shall consist of one member of each of the 4 pairs of side-by-side collected samples. In addition, 8 bulk samples shall be randomly selected from the 26 single samples and shall be analyzed by two different analysts within MRI (duplicate analysis). Eight bulk samples shall be randomly selected for replicate analysis (2 independent preparations from the same sample).

**TABLE 3. SAMPLE SELECTION FOR QA ANALYSIS - SCHOOL 1**

| | | Field Blanks | | | | 35-hour Millipore filters | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | NA | PA | UA | O | NA | PA | UA | O | |
| Sampled | | 3 | 3 | 10 | 1 | 6 | 6 | 27 | 2 | 58 |
| Test Filters to be Analyzed | TEM | 1 | 1 | 1 | 1 | 6 | 6 | 27 | 2 | 45 |
| | PCM | - | - | - | - | 6 | 6 | 27 | 2 | 41 |
| External QA | TEM | | | | | 1 | 1 | 4 | 1 | 7 |
| | PCM | | | | | 2 | 2 | 8 | 2 | 14 |
| Replicate Analyses | TEM | | | | | 1 | 1 | 4 | 1 | 7 |
| | PCM | | | | | 2 | 2 | 8 | 2 | 14 |
| Duplicate Analyses | TEM | | | | | 1 | 1 | 4 | 1 | 7 |
| | PCM | | | | | 2 | 2 | 8 | 2 | 14 |
| Laboratory Blanks | TEM | 3 at main and 3 at external QA laboratory | | | | | | | | |
| | PCM | 3 at main and 3 at external QA laboratory | | | | | | | | |

UA = Unpainted Asbestos NA = Non-asbestos
PA = Painted Asbestos O = Outdoor

**TABLE 4. SAMPLE SELECTION FOR QA ANALYSES - SCHOOL 2
SAMPLING PERIOD #1 ONLY**

| | | Field Blanks | | 35-hour Millipore filters | | Total |
|---|---|---|---|---|---|---|
| | | PA | O | PA | O | |
| Sampled | | 4 | 1 | 8 | 2 | 15 |
| Test Filters to be Analyzed | TEM | 1 | 1 | 8 | 2 | 12 |
| | PCM | - | - | 8 | 2 | 10 |
| External QA | TEM | | | 2 | 0 | 2 |
| | PCM | | | 2 | 0 | 2 |
| Replicate Analyses | TEM | | | 2 | 1 | 3 |
| | PCM | | | 2 | 1 | 3 |
| Duplicate Analyses | TEM | | | 2 | 1 | 3 |
| | PCM | | | 2 | 1 | 3 |

PA = Painted Asbestos
O = Outdoor

# 17.0 ROTAMETER CALIBRATION PROCEDURES AND REFERENCE MATERIALS

## 17.1 Rotameter Calibration Procedure

1. Record the preliminary data at the top of the data sheet shown in Figure 2.
2. Set-up the calibration system as shown in Figure 3. Allow the wet test meter to run for 20 min. 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 ($\Delta P$) 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.
10. Calculate the flow rates for each setting using the equation:

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

Flowmeter type _____ Tube _____

MRI or I.D. no. _____ Date _____

Barometric pressure, Pb _____ "$H_2O$ Initial _____

Standard pressure, Ps _____ "$H_2O$ Standard temp, Ts _____ ° K

| 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

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

FIGURE 2. FLOWMETER CALIBRATION DATAFORM

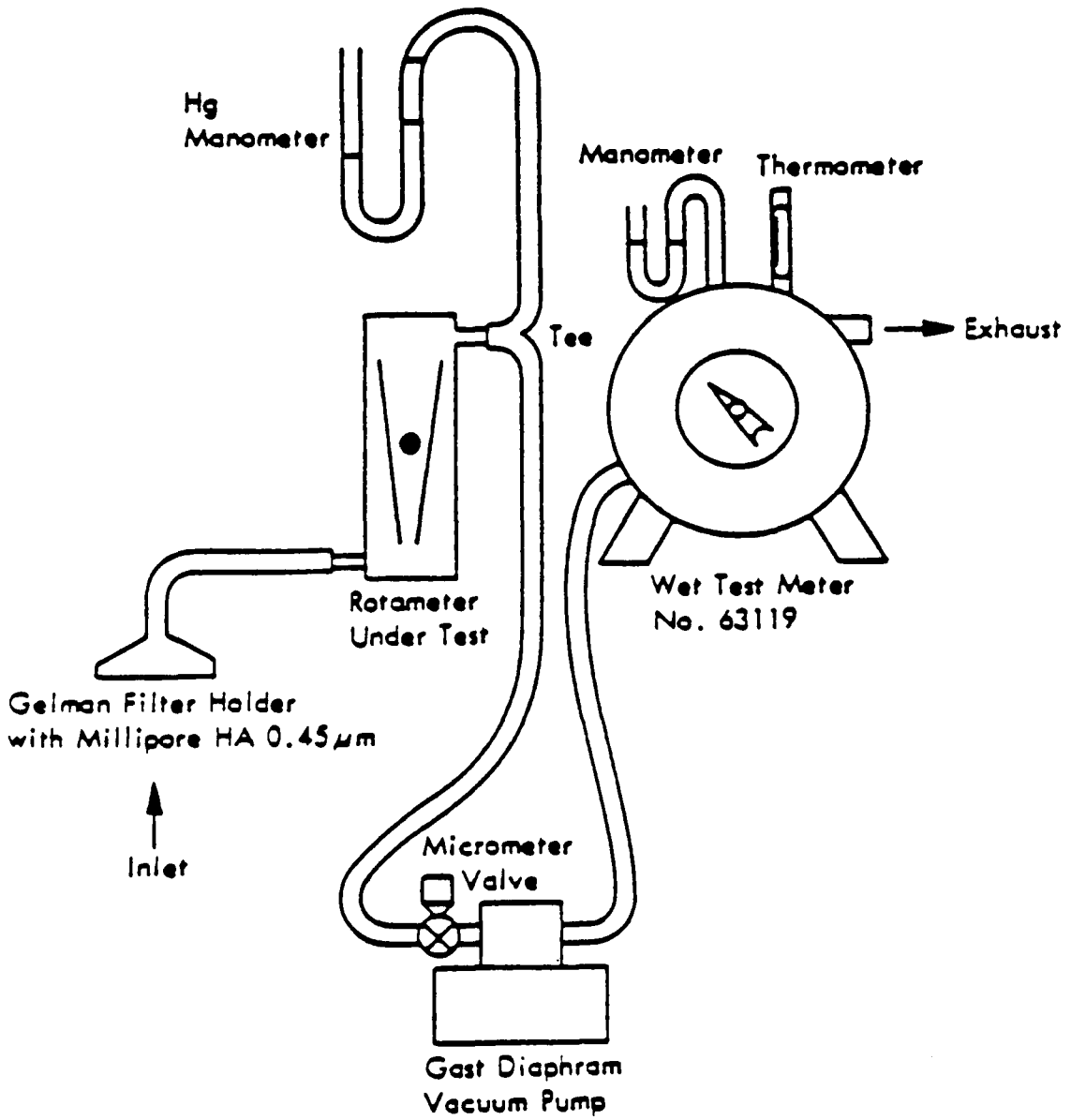



FIGURE 3. ROTAMETER CALIBRATION SYSTEM

where:

$Q$ = flow rate in standard cc/min,

$V_w$ = wet test meter volume in cc,

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

Time =time in minutes,

$P_b$ =barometric pressure in inches of $H_2O$,

$V_p$ =vapor pressure in inches of $H_g$,

$\Delta p$ =manometer reading in inches of $H_2O$,

$P_s$ =standard pressure in inches of $H_2O$,

$T_s$ =standard temperature in $^oK$, and

$T_w$ =wet test meter temperature in $^oC$.

10. Plot rotameter readings versus values of Q for each setting as shown in Figure 4.

## 17.2 Rotameter Calibration Schedule

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

## 17.3 Reference Materials

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

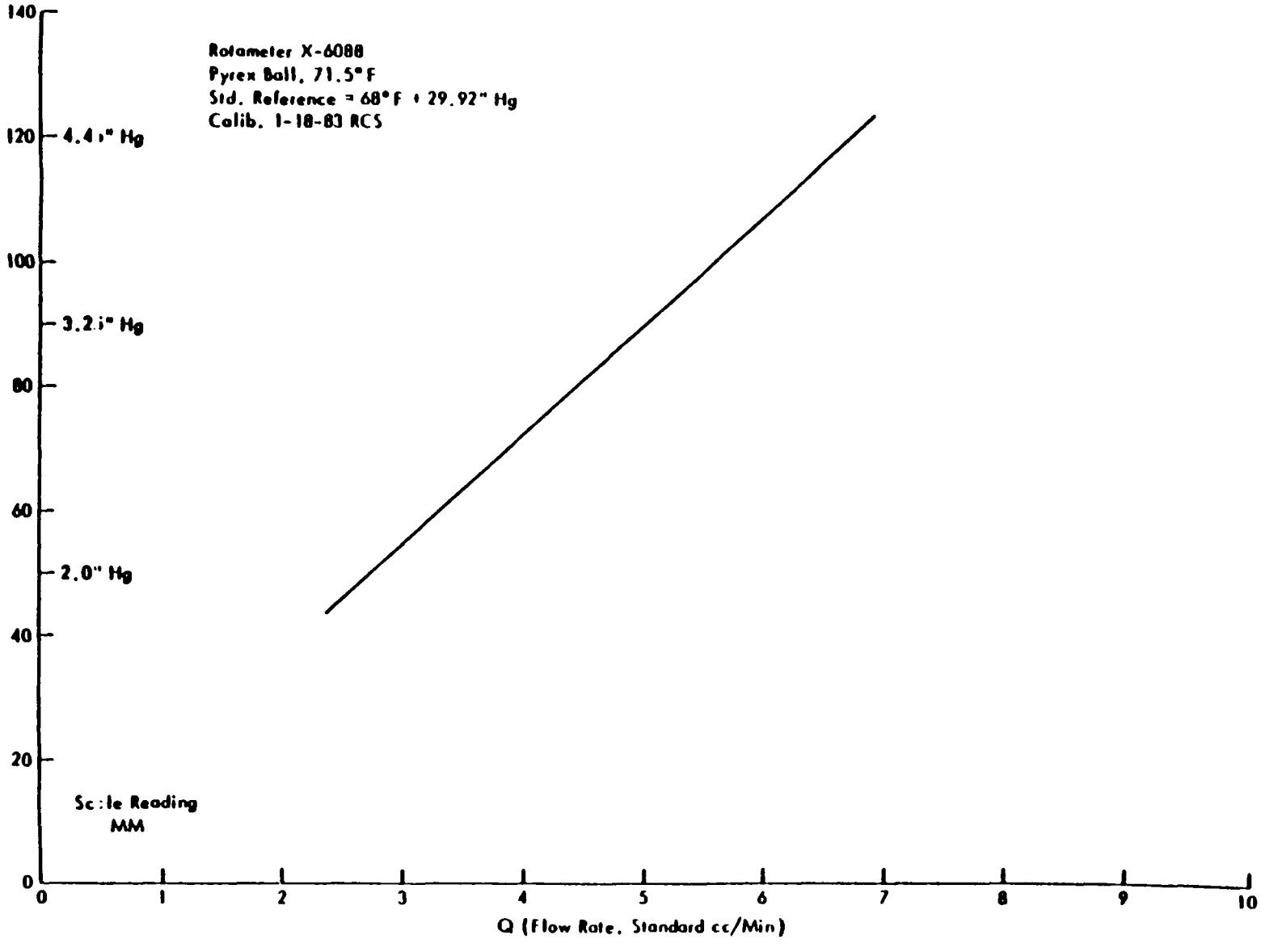



FIGURE 4. PLOT OF ROTAMETER READINGS VERSUS VALUES OF Q

## 18.0 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.

## 19.0 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 encapsulation) using analysis of variance techniques. If necessary, transformations of the data shall be made to achieve homogeneity of variance.

Samples analyzed by TEM and PCM shall be compared by calculating correlation coefficients and estimating constant and relative biases for each method relative to the other.

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.

## 20.0 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.

## 21.0 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.

### 21.1 Performance Audits

| Device to be Audited | Audit 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 $\pm$ 10% as compared to the audit device.

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

## 21.2 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 B

## SAMPLING AND ANALYSIS PROTOCOLS

# APPENDIX B-1

## AIR SAMPLING PROTOCOL

Airborne asbestos sampling will be conducted according to the general procedure outlined by Price et al. (1980). 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.

### SELECTION OF SAMPLING LOCATION

#### 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).

#### Outside Ambient

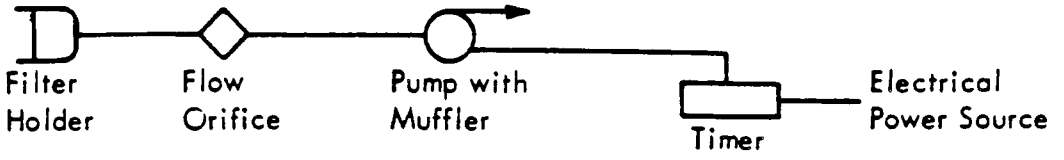
The location of the outside ambient sampler is important to obtain a representative background measure. This sampler, thus, should be placed upwind of the building if it is to represent such that no bias is created by identifiable local sources (e.g., parking lots, highways, and building exhaust) With 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.

### 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:




SAMPLING PROTOCOL

1. Clean and dry filterholder 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.

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 a 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 in a horizontal (flat) position at all times (handling, transport, and storage).

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.

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.

LOGBOOK 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.

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.

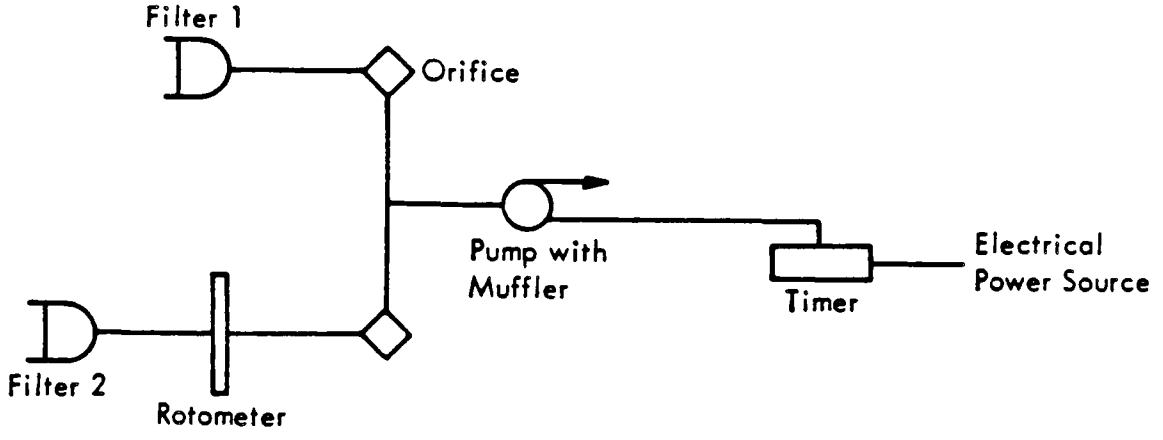
If possible, conduct a midweek site check of points 1-5.

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.).

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:

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

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

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

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

REFERENCES

Price B, Melton C, Schmidt E, Townley C. 1980. Battelle Columbus Labs. Airborne asbestos levels in schools: a design study. Report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract 68-01-3858.

## APPENDIX B-2

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

The specific points where bulk samples will be taken will be designated by the statistician at Battelle Columbus Laboratories who was involved in the air sampling survey design.

### 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). Side-by-side samples will be taken at points designated to provide duplicates for quality assurance. This procedure eliminates the necessity of splitting samples at a later time.

An identification number will be assigned to each sample. This number will also appear on the sampler container, in the field logbook along with descriptive information, and on the chain-of-custody records. These numbers will be sent to the field on preprinted replicate gum labels that have other pertinent information on them.

### SAMPLE HANDLING

The samples will be shipped by the field crew to the attention of the quality control representative at MRI, who will log them in and assign them permanent numbers on a random basis. The quality control representative will then identify and remove the duplicates and, from this set of duplicates, choose, on a random basis, a number of them for analysis by an external laboratory. The remaining duplicates will be put back with the remaining samples, and all of these will be given to the MRI analyst for analysis. Duplicate samples will be sent to an external laboratory for quality assurance analysis.

### ANALYSIS

The samples will be analyzed by polarized light microscopy 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.

### 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 WC. 1980. The asbestos particle atlas. Ann 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, DC: 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 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 B-4

## 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/$m^3$ =

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

Mass Concentration ($ng/m^3$) =

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

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 $3.0 \times 10^{-3}$ $ng/\mu m^3$ for amphibole and $2.6 \times 10^{-3} ng/\mu m^3$ for chrysotile. $\text{Length}_i$ is the length of fiber i in $\mu m$ and $\text{width}_i$ is the width of fiber i in $\mu m$. (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 C

## RESULTS OF SAMPLE ANALYSIS

# APPENDIX C-1
# TEM RESULTS

| ID | | PERIOD | SCHOOL | SITE | FILTER* | TYPE** | TYPE*** | # FIBERS | Fib/m$^3$ | ng/m$^3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| WD-36 | 1 | 1 | 1 | 8 | 2 | UA | S | 103 | 7.83E+05 | 3.18E+00 |
| WD-38 | 2 | 1 | 1 | 7 | 1 | UA | S | 15 | 8.20E+04 | 3.80E-01 |
| WD-40 | 3 | 1 | 1 | 15 | 1 | NA | S | 54 | 3.00E+05 | 1.10E+00 |
| WD-30 | 4 | 1 | 1 | 1 | 2 | UA | S | 373 | 4.02E+07 | 2.00E+02 |
| WD-49 | 5 | 1 | 1 | 4 | 3 | UA | S | 101 | 2.16E+06 | 9.41E+00 |
| WD-43 | 6 | 1 | 1 | 11 | 2 | PA | S | 52 | 8.10E+04 | 3.30E-01 |
| WD-23 | 7 | 1 | 1 | 11 | 0 | FB | S | 2 | . | . |
| WD-27 | 8 | 1 | 1 | 17 | 2 | O | S | 2 | 3.00E+03 | 9.00E-03 |
| WD-59 | 9 | 1 | 1 | 6 | 2 | UA | S | 132 | 3.52E+06 | 1.51E+01 |
| WD-11 | 10 | 1 | 2 | 1 | 0 | FB | S | 1 | . | . |
| WD-56 | 11 | 1 | 1 | 13 | 2 | PA | S | 146 | 1.11E+06 | 4.61E+00 |
| WD-60 | 12 | 1 | 1 | 14 | 1 | NA | S | 107 | 2.04E+05 | 9.70E-01 |
| WD-62 | 13 | 1 | 1 | 5 | 3 | UA | S | 312 | 4.14E+06 | 2.44E+01 |
| WD-66 | 14 | 1 | 1 | 16 | 2 | NA | S | 37 | 5.80E+04 | 3.30E-01 |
| WD-67 | 15 | 1 | 2 | 2 | 1 | PA | S | 124 | 6.09E+06 | 3.25E+01 |
| WD-69 | 16 | 1 | 2 | 3 | 1 | PA | S | 134 | 1.96E+06 | 1.07E+01 |
| WD-72 | 17 | 1 | 2 | 4 | 2 | PA | S | 210 | 1.05E+07 | 6.20E+01 |
| WD-50 | 18 | 1 | 1 | 10 | 1 | UA | S | 54 | 2.80E+05 | 1.60E+00 |
| WD-33 | 19 | 1 | 1 | 2 | 1 | UA | S | 131 | 9.20E+05 | 4.66E+00 |
| WD-71 | 20 | 1 | 2 | 4 | 1 | PA | S | 150 | 2.85E+06 | 1.63E+01 |
| WD-29 | 21 | 1 | 1 | 1 | 1 | UA | S | 124 | 3.27E+06 | 1.81E+01 |
| WD-47 | 22 | 1 | 1 | 4 | 1 | UA | S | 31 | 1.60E+05 | 7.50E-01 |
| WD-54 | 23 | 1 | 1 | 9 | 2 | UA | S | 103 | 2.87E+06 | 1.21E+01 |
| WD-31 | 24 | 1 | 1 | 12 | 1 | PA | S | 101 | 2.64E+06 | 1.36E+01 |
| WD-47 | 25 | 1 | 1 | 4 | 1 | UA | D | 43 | 2.20E+05 | 1.50E+00 |
| WD-71 | 26 | 1 | 2 | 4 | 1 | PA | D | 143 | 4.08E+06 | 1.83E+01 |
| WD-29 | 27 | 1 | 1 | 1 | 1 | UA | R | 166 | 4.38E+06 | 2.47E+01 |
| WD-48 | 28 | 1 | 1 | 4 | 2 | UA | S | 115 | 1.14E+06 | 4.91E+00 |
| WD-68 | 29 | 1 | 2 | 2 | 2 | PA | S | 173 | 8.94E+06 | 4.01E+01 |
| WD-68 | 30 | 1 | 2 | 2 | 2 | PA | R | 366 | 5.41E+06 | 2.60E+01 |
| WMG-19 | 31 | 3 | 1 | 7 | 1 | UA | S | 11 | 1.40E+04 | 7.10E-02 |
| WMG-21 | 32 | 3 | 1 | 8 | 3 | UA | S | 8 | 9.00E+03 | 6.00E-02 |
| WMG-20 | 33 | 3 | 1 | 7 | 2 | UA | S | 29 | 3.70E+04 | 2.00E-01 |
| WMG-42 | 34 | 3 | 1 | 15 | 2 | NA | S | 9 | 1.00E+04 | 7.00E-02 |
| WMG-35 | 35 | 3 | 1 | 13 | 1 | PA | S | 17 | 2.30E+04 | 9.70E-02 |
| WMG-38 | 36 | 3 | 1 | 14 | 2 | NA | S | 5 | 7.00E+03 | 2.00E-02 |
| WMG-40 | 37 | 3 | 1 | 2 | 2 | UA | S | 16 | 2.20E+04 | 9.30E-02 |
| WMG-43 | 38 | 3 | 1 | 16 | 1 | NA | S | 5 | 7.00E+03 | 3.00E-02 |
| WMG-46 | 39 | 3 | 1 | 3 | 2 | UA | S | 2 | 3.00E+03 | 9.00E-03 |
| WMG-33 | 40 | 3 | 1 | 5 | 1 | UA | S | 16 | 2.40E+04 | 8.40E-02 |
| WMG-49 | 41 | 3 | 1 | 11 | 2 | PA | S | 18 | 2.80E+04 | 9.20E-02 |
| WMG-17 | 42 | 3 | 1 | 5 | 0 | FB | S | 7 | . | . |
| WG-31 | 43 | 2 | 1 | 24 | 2 | UA | S | 67 | 1.10E+05 | 5.30E-01 |
| WD-48 | 44 | 1 | 1 | 4 | 2 | UA | R | 137 | 1.94E+05 | 8.22E-01 |
| WG-37 | 45 | 2 | 1 | 27 | 2 | UA | S | 68 | 1.20E+05 | 7.00E-01 |
| WG-39 | 46 | 2 | 1 | 23 | 2 | UA | S | 84 | 1.30E+05 | 7.80E-01 |
| WG-35 | 47 | 2 | 1 | 28 | 2 | UA | S | 27 | 4.30E+04 | 1.90E-01 |
| WG-40 | 48 | 2 | 1 | 16 | 1 | NA | S | 9 | 2.00E+04 | 6.00E-02 |
| WMG-55 | 49 | 3 | 1 | 9 | 3 | UA | S | 22 | 2.60E+04 | 9.90E-02 |
| WMG-57 | 50 | 3 | 1 | 10 | 2 | UA | S | 20 | 2.70E+04 | 1.90E-01 |
| WG-32 | 51 | 2 | 1 | 25 | 1 | UA | S | 50 | 8.20E+04 | 5.60E-01 |
| WD-70 | 52 | 1 | 2 | 3 | 2 | PA | S | 105 | 1.02E+07 | 3.97E+01 |
| WMG-53 | 53 | 3 | 1 | 9 | 1 | UA | S | 1 | 1.00E+03 | 7.00E-03 |
| WG-13 | 54 | 2 | 1 | 22 | 0 | FB | S | 12 | . | . |
| WG-38 | 55 | 2 | 1 | 23 | 1 | UA | S | 14 | 2.20E+04 | 8.00E-02 |
| WG-45 | 56 | 2 | 1 | 15 | 2 | NA | S | 6 | 1.00E+04 | 4.00E-02 |
| WG-50 | 57 | 2 | 1 | 4 | 3 | IB | S | 24 | 2.60E+05 | 1.60E+00 |
| WG-22 | 58 | 2 | 1 | 98 | 1 | PP | S | 0 | 0.00E+00 | 0.00E+00 |
| WG-1 | 59 | 2 | 1 | 92 | 1 | PP | S | 15 | 6.00E+08 | 1.30E+04 |
| WG-55 | 60 | 2 | 1 | 3 | 2 | IB | S | 4 | 2.00E+05 | 6.00E-01 |
| WG-67 | 61 | 2 | 1 | 10 | 1 | IB | S | 34 | 1.70E+06 | 9.40E+00 |
| WG-72 | 62 | 2 | 1 | 9 | 2 | IB | S | 9 | 5.00E+05 | 3.00E+00 |

* Filter
0 = blank
1-2 = side-by-side
3 = opposite side of room

** Type
UA = unpainted asbestos
PA = painted asbestos
NA = non-asbestos
O = outdoor
IB = inside barrier
FB = field blank
LB = lab blank
MP = mobile pump
PP = personal pump

*** Type of Analysis
S = standard
D = duplicate
R = replicate

# APPENDIX C-1 (Continued)
# TEM RESULTS

| ID | | PERIOD | SCHOOL | SITE | FILTER* | TYPE** | TYPE*** | # FIBERS | fib/m$^3$ | ng/m$^3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| WG-2 | 63 | 2 | 1 | 93 | 1 | PP | S | 4 | 3.00E+08 | 1.00E+03 |
| WG-11 | 64 | 2 | 1 | 94 | 1 | PP | S | 10 | 4.40E+08 | 2.30E+03 |
| WMG-19 | 65 | 3 | 1 | 7 | 1 | UA | R | 13 | 1.70E+04 | 6.60E-02 |
| WMG-46 | 66 | 3 | 1 | 3 | 2 | UA | R | 3 | 4.00E+03 | 1.00E-02 |
| WG-48 | 67 | 2 | 1 | 18 | 1 | IB | S | 10 | 2.60E+05 | 3.50E+00 |
| WG-12 | 68 | 2 | 1 | 95 | 1 | PP | S | 0 | 0.00E+00 | 0.00E+00 |
| WMG-59 | 69 | 3 | 1 | 17 | 2 | O | S | 2 | 3.00E+03 | 1.00E-02 |
| WG-69 | 70 | 2 | 1 | 10 | 3 | IB | S | 14 | 5.90E+05 | 3.90E+00 |
| WG-43 | 71 | 2 | 1 | 14 | 2 | NA | S | 0 | 0.00E+00 | 0.00E+00 |
| WG-23 | 72 | 2 | 1 | 97 | 1 | PP | S | 20 | 1.80E+08 | 1.70E+03 |
| WMG-23 | 73 | 3 | 1 | 8 | 2 | UA | S | 37 | 4.70E+04 | 2.20E-01 |
| WG-57 | 74 | 2 | 1 | 19 | 1 | IB | S | 3 | 1.00E+05 | 7.00E-01 |
| WG-75 | 75 | 2 | 1 | 17 | 2 | O | S | 0 | 0.00E+00 | 0.00E+00 |
| WMG-27 | 76 | 3 | 1 | 12 | 1 | PA | S | 0 | 0.00E+00 | 0.00E+00 |
| WG-27 | 77 | 2 | 1 | 91 | 2 | MP | S | 111 | 8.34E+07 | 1.68E+03 |
| WG-27 | 78 | 2 | 1 | 91 | 2 | MP | D | 106 | 1.43E+09 | 1.58E+04 |
| WMG-24 | 79 | 3 | 1 | 1 | 1 | UA | S | 1 | 1.00E+03 | 3.00E-03 |
| WMG-30 | 80 | 3 | 1 | 6 | 2 | UA | S | 11 | 1.50E+04 | 1.20E-01 |
| WG-52 | 81 | 2 | 1 | 4 | 2 | IB | S | 0 | 0.00E+00 | 0.00E+00 |
| WG-25 | 82 | 2 | 1 | 90 | 2 | MP | S | 36 | 6.30E+07 | 3.80E+02 |
| WG-24 | 83 | 2 | 1 | 90 | 1 | MP | S | 27 | 4.70E+07 | 3.90E+02 |
| WG-26 | 84 | 2 | 1 | 91 | 1 | MP | S | 3 | 4.00E+06 | 4.00E+01 |
| WD-57 | 85 | 1 | 1 | 6 | 3 | UA | S | 113 | 2.42E+06 | 9.95E+00 |
| WD-57 | 86 | 1 | 1 | 6 | 3 | UA | D | 127 | 1.36E+06 | 7.72E+00 |
| WMG-51 | 87 | 3 | 1 | 4 | 1 | UA | S | 13 | 6.30E+04 | 6.80E-01 |
| WMG-23 | 88 | 3 | 1 | 8 | 2 | UA | D | 37 | 4.70E+04 | 1.60E-01 |
| WMG-53 | 89 | 3 | 1 | 9 | 1 | UA | D | 0 | 0.00E+00 | 0.00E+00 |
| WG-61 | 90 | 2 | 1 | 21 | 3 | IB | S | 26 | 7.70E+05 | 5.40E+00 |
| WG-28 | 91 | 2 | 1 | 22 | 1 | UA | S | 117 | 1.45E+06 | 6.29E+00 |
| WG-65 | 92 | 2 | 1 | 20 | 2 | IB | S | 27 | 3.10E+06 | 1.80E+01 |
| WG-54 | 93 | 2 | 1 | 3 | 1 | IB | S | 2 | 1.00E+05 | 3.00E-01 |
| WG-69 | 94 | 2 | 1 | 10 | 3 | IB | D | 29 | 1.20E+06 | 5.10E+00 |
| WG-50 | 95 | 2 | 1 | 4 | 3 | IB | R | 34 | 3.70E+05 | 2.30E+00 |
| WG-54 | 96 | 2 | 1 | 3 | 1 | IB | D | 2 | 1.00E+05 | 5.00E-01 |
| WG-38 | 97 | 2 | 1 | 23 | 1 | UA | R | 8 | 1.00E+04 | 5.00E-02 |
| WD-63 | 98 | 1 | 1 | 5 | 1 | UA | S | 111 | 1.81E+06 | 7.10E+00 |
| WZ-30 | 99 | 4 | 1 | 7 | 2 | UA | S | 49 | 6.30E+04 | 3.60E-01 |
| WZ-41 | 100 | 4 | 1 | 13 | 1 | PA | S | 17 | 2.30E+04 | 9.50E-02 |
| WG-56 | 101 | 2 | 1 | 19 | 3 | IB | S | 0 | 0.00E+00 | 0.00E+00 |
| WG-63 | 102 | 2 | 1 | 20 | 3 | IB | S | 3 | 3.00E+05 | 2.00E+00 |
| WMG-26 | 103 | 3 | 1 | 1 | 3 | UA | S | 4 | 5.00E+03 | 2.00E-02 |
| WD-3 | 104 | 1 | 0 | 0 | 0 | LB | S | 1 | . | . |
| WMG-50 | 105 | 3 | 1 | 4 | 3 | UA | S | 0 | 0.00E+00 | 0.00E+00 |
| WMG-32 | 106 | 3 | 1 | 5 | 3 | UA | S | 0 | 0.00E+00 | 0.00E+00 |
| WZ-14 | 107 | 4 | 1 | 17 | 0 | FB | S | 0 | . | . |
| WZ-23 | 108 | 4 | 1 | 17 | 2 | O | S | 0 | 0.00E+00 | 0.00E+00 |
| WD-27 | 109 | 1 | 1 | 17 | 2 | O | D | 3 | 4.00E+03 | 2.00E-02 |
| WD-38 | 110 | 1 | 1 | 7 | 1 | UA | D | 52 | 2.80E+05 | 1.10E+00 |
| WZ-5 | 111 | 4 | 1 | 12 | 0 | FB | S | 7 | . | . |
| WZ-17 | 112 | 4 | 1 | 7 | 0 | FB | S | 0 | . | . |
| WZ-45 | 113 | 4 | 1 | 5 | 1 | UA | S | 85 | 1.50E+05 | 8.80E-01 |
| WMG-33 | 114 | 3 | 1 | 5 | 1 | UA | D | 4 | 6.00E+03 | 2.00E-02 |
| WD-56 | 115 | 1 | 1 | 13 | 2 | PA | D | 150 | 1.14E+06 | 4.37E+00 |
| WG-65 | 116 | 2 | 1 | 20 | 2 | IB | R | 4 | 2.00E+05 | 2.00E+00 |
| WZ-37 | 117 | 4 | 1 | 9 | 1 | UA | S | 80 | 1.10E+05 | 4.60E-01 |
| WMG-43 | 118 | 3 | 1 | 16 | 1 | NA | D | 12 | 1.60E+04 | 7.80E-02 |
| WG-35 | 119 | 2 | 1 | 26 | 2 | UA | D | 28 | 4.50E+04 | 2.80E-01 |
| WG-57 | 120 | 2 | 1 | 19 | 1 | IB | R | 0 | 0.00E+00 | 0.00E+00 |
| WD-69 | 121 | 1 | 2 | 3 | 1 | PA | R | 105 | 5.37E+06 | 2.43E+01 |
| WMG-51 | 122 | 3 | 1 | 4 | 1 | UA | R | 1 | 1.00E+03 | 5.00E-03 |
| WMG-59 | 123 | 3 | 1 | 17 | 2 | O | R | 9 | 1.00E+04 | 7.00E-02 |
| WCD-2 | 124 | 4 | 1 | 2 | 2 | UA | S | 61 | 8.80E+04 | 4.20E-01 |

* Filter
O = blank
1-2 = side-by-side
3 = opposite side of room

** Type
UA = unpainted asbestos
PA = painted asbestos
NA = non-asbestos
O = outdoor
IB = inside barrier
FB = field blank
LB = lab blank
MP = mobile pump
PP = personal pump

*** Type of Analysis
S = standard
D = duplicate
R = replicate

# APPENDIX C-1 (Continued)
# TEM RESULTS

| ID | | PERIOD | SCHOOL | SITE | FILTER* | TYPE** | TYPE*** | # FIBERS | fib/m³ | ng/m³ |
|---|---|---|---|---|---|---|---|---|---|---|
| WZ-44 | 125 | 4 | 1 | 5 | 2 | UA | S | 104 | 1.94E+06 | 8.27E+00 |
| WG-40 | 126 | 2 | 1 | 16 | 1 | NA | D | 3 | 5.00E+03 | 2.00E-02 |
| WG-72 | 127 | 2 | 1 | 9 | 2 | IB | D | 4 | 2.00E+05 | 1.00E+00 |
| WD-60 | 128 | 1 | 1 | 14 | 1 | NA | D | 139 | 3.10E+05 | 1.57E+00 |
| WZ-41 | 129 | 4 | 1 | 13 | 1 | PA | D | 27 | 3.60E+04 | 1.70E-01 |
| WG-29 | 130 | 2 | 1 | 22 | 2 | UA | S | 23 | 4.00E+04 | 3.70E-01 |
| WMG-47 | 131 | 3 | 1 | 3 | 3 | UA | S | 3 | 4.00E+03 | 2.00E-02 |
| WD-74 | 132 | 1 | 2 | 1 | 2 | PA | S | 123 | 9.38E+05 | 8.69E+00 |
| WD-70 | 133 | 1 | 2 | 3 | 2 | PA | D | 101 | 9.82E+06 | 4.41E+01 |
| WZ-30 | 134 | 4 | 1 | 7 | 2 | UA | D | 102 | 1.71E+05 | 7.46E-01 |
| WMG-22 | 135 | 3 | 1 | 8 | 1 | UA | S | 2 | 3.00E+03 | 1.00E-02 |
| WG-47 | 136 | 2 | 1 | 18 | 3 | IB | S | 4 | 4.00E+05 | 2.00E+00 |
| WG-53 | 137 | 2 | 1 | 3 | 3 | IB | S | 4 | 2.00E+05 | 2.00E+00 |
| WG-70 | 138 | 2 | 1 | 9 | 3 | IB | S | 14 | 7.70E+05 | 5.00E+00 |
| WZ-32 | 139 | 4 | 1 | 4 | 1 | UA | S | 101 | 1.38E+06 | 5.23E+00 |
| WZ-22 | 140 | 4 | 1 | 17 | 1 | O | S | 6 | 8.00E+03 | 2.00E-02 |
| WZ-36 | 141 | 4 | 1 | 9 | 3 | UA | S | 126 | 1.55E+06 | 5.52E+00 |
| WMG-31 | 142 | 3 | 1 | 6 | 3 | UA | S | 48 | 6.00E+04 | 3.40E-01 |
| WZ-40 | 143 | 4 | 1 | 16 | 2 | NA | S | 19 | 2.80E+04 | 1.10E-01 |
| WZ-48 | 144 | 4 | 1 | 6 | 2 | UA | S | 16 | 2.60E+04 | 2.20E-01 |
| WZ-22 | 145 | 4 | 1 | 17 | 1 | O | D | 3 | 4.00E+03 | 1.00E-02 |
| WZ-42 | 146 | 4 | 1 | 13 | 2 | PA | S | 109 | 3.68E+05 | 1.49E+00 |
| WZ-10 | 147 | 4 | 1 | 16 | 0 | FB | S | 2 | . | . |
| WMG-50 | 148 | 3 | 1 | 4 | 3 | UA | D | 9 | 1.00E+04 | 1.00E-01 |
| WZ-36 | 149 | 4 | 1 | 9 | 3 | UA | D | 170 | 1.05E+06 | 5.75E+00 |
| WZ-22 | 150 | 4 | 1 | 17 | 1 | O | R | 4 | 5.00E+03 | 3.00E-02 |
| WZ-48 | 151 | 4 | 1 | 6 | 2 | UA | D | 72 | 1.10E+05 | 5.60E-01 |
| WG-78 | 152 | 2 | 0 | 0 | 0 | LB | S | 0 | . | . |
| WG-77 | 153 | 2 | 0 | 0 | 0 | LB | S | 4 | . | . |
| WZ-42 | 154 | 4 | 1 | 13 | 2 | PA | R | 101 | 1.78E+05 | 9.79E-01 |
| WZ-32 | 155 | 4 | 1 | 4 | 1 | UA | R | 102 | 1.39E+06 | 4.49E+00 |
| WMG-49 | 156 | 3 | 1 | 11 | 2 | PA | R | 15 | 2.30E+04 | 1.00E-01 |
| WZ-48 | 157 | 4 | 1 | 6 | 2 | UA | R | 46 | 7.30E+04 | 5.60E-01 |
| WD-66 | 158 | 1 | 1 | 16 | 2 | NA | R | 64 | 3.50E+05 | 2.10E+00 |
| WG-59 | 159 | 2 | 1 | 21 | 1 | IB | S | 2 | 3.00E+05 | 1.00E+00 |
| WD-1 | 160 | 1 | 0 | 0 | 0 | LB | S | 6 | . | . |
| WMG-31 | 161 | 3 | 1 | 6 | 3 | UA | R | 61 | 7.70E+04 | 5.20E-01 |
| WZ-45 | 162 | 4 | 1 | 5 | 1 | UA | D | 105 | 1.84E+05 | 8.37E-01 |
| WCD-3 | 163 | 4 | 1 | 15 | 1 | NA | S | 82 | 1.20E+05 | 5.10E-01 |
| WCD-6 | 164 | 4 | 1 | 8 | 2 | UA | S | 15 | 7.40E+04 | 4.30E-01 |
| WCD-8 | 165 | 4 | 1 | 3 | 1 | UA | S | 124 | 6.05E+05 | 2.97E+00 |
| WCD-1 | 166 | 4 | 1 | 2 | 1 | UA | S | 96 | 1.50E+05 | 8.60E-01 |
| WZ-44 | 167 | 4 | 1 | 5 | 2 | UA | R | 102 | 3.81E+05 | 1.92E+00 |
| WZ-40 | 168 | 4 | 1 | 16 | 2 | NA | D | 19 | 2.80E+04 | 1.20E-01 |
| WCD-2 | 169 | 4 | 1 | 2 | 2 | UA | R | 104 | 1.51E+05 | 6.81E-01 |
| WCD-10 | 170 | 4 | 1 | 3 | 3 | UA | S | 14 | 1.70E+04 | 1.10E-01 |
| WCD-4 | 171 | 4 | 1 | 15 | 2 | NA | S | 46 | 6.90E+04 | 3.00E-01 |
| WCD-13 | 172 | 4 | 1 | 14 | 1 | NA | R | 9 | 1.00E+04 | 4.00E-02 |
| WZ-38 | 173 | 4 | 1 | 9 | 2 | UA | S | 111 | 4.57E+05 | 3.08E+00 |
| WZ-47 | 174 | 4 | 1 | 6 | 1 | UA | S | 1 | 1.00E+03 | 6.00E-03 |
| WZ-2 | 175 | 4 | 0 | 0 | 0 | LB | S | 4 | | |
| WZ-26 | 176 | 4 | 1 | 1 | 3 | UA | S | 108 | 1.61E+06 | 6.67E+00 |
| WZ-34 | 177 | 4 | 1 | 11 | 1 | PA | S | 48 | 6.40E+04 | 3.60E-01 |
| WZ-3 | 178 | 4 | 0 | 0 | 0 | LB | S | 6 | | |
| WCD-8 | 179 | 4 | 1 | 3 | 1 | UA | R | 110 | 2.10E+05 | 1.00E+00 |
| WCD-9 | 180 | 4 | 1 | 3 | 2 | UA | S | 104 | 5.07E+05 | 2.87E+00 |
| WCD-14 | 181 | 4 | 1 | 14 | 2 | NA | S | 8 | 1.00E+04 | 8.00E-02 |
| WZ-27 | 182 | 4 | 1 | 1 | 1 | UA | S | 103 | 1.64E+05 | 7 46E-01 |
| WCD-13 | 183 | 4 | 1 | 14 | 1 | NA | S | 1 | 1.00E+03 | 1.00E-02 |
| WZ-39 | 184 | 4 | 1 | 16 | 1 | NA | S | 35 | 5.10E+04 | 2.00E-01 |
| WZ-43 | 185 | 4 | 1 | 5 | 3 | UA | S | 101 | 2.78E+05 | 1.37E+00 |
| WZ-33 | 186 | 4 | 1 | 4 | 2 | UA | S | 133 | 8.65E+05 | 4.03E+00 |
| WZ-35 | 187 | 4 | 1 | 11 | 2 | PA | S | 127 | 3.99E+05 | 1.71E+00 |
| WCD-5 | 188 | 4 | 1 | 8 | 1 | UA | S | 7 | 7.00E+04 | 1.00E-01 |

* Filter
0 = blank
1-2 = side-by-side
3 = opposite side of room

** Type
UA = unpainted asbestos
PA = painted asbestos
NA = non-asbestos
O = outdoor
IB = inside barrier
FB = field blank
LB = lab blank
MP = mobile pump
PP = personal pump

*** Type of Analysis
S = standard
D = duplicate
R = replicate

APPENDIX C-2

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD FIBER-COUNTS | TEM-CHRYS-DUPLICATE FIBER-COUNTS |
|---|---|---|
| WD-27 | 2 | 3 |
| WD-38 | 15 | 52 |
| WD-47 | 31 | 43 |
| WD-56 | 146 | 150 |
| WD-57 | 113 | 127 |
| WD-60 | 107 | 139 |
| WD-70 | 105 | 101 |
| WD-71 | 150 | 143 |
| WG-27 | 111 | 106 |
| WG-35 | 27 | 28 |
| WG-40 | 9 | 3 |
| WG-54 | 2 | 2 |
| WG-69 | 14 | 29 |
| WG-72 | 9 | 4 |
| WMG-23 | 37 | 37 |
| WMG-33 | 16 | 4 |
| WMG-43 | 5 | 12 |
| WMG-50 | 0 | 9 |
| WMG-53 | 1 | 0 |
| WZ-22 | 6 | 3 |
| WZ-30 | 49 | 102 |
| WZ-36 | 126 | 170 |
| WZ-40 | 19 | 19 |
| WZ-41 | 17 | 27 |
| WZ-45 | 85 | 105 |
| WZ-48 | 16 | 72 |

APPENDIX C-2 (continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD FIBER-COUNTS | TEM-CHRYS-REPLICATE FIBER-COUNTS |
|---|---|---|
| WCD-13 | 1 | 9 |
| WCD-2 | 61 | 104 |
| WCD-8 | 124 | 110 |
| WD-29 | 124 | 166 |
| WD-48 | 115 | 137 |
| WD-66 | 37 | 64 |
| WD-68 | 173 | 366 |
| WD-69 | 134 | 105 |
| WG-38 | 14 | 8 |
| WG-50 | 24 | 34 |
| WG-57 | 3 | 0 |
| WG-65 | 27 | 4 |
| WMG-19 | 11 | 13 |
| WMG-31 | 48 | 61 |
| WMG-46 | 2 | 3 |
| WMG-49 | 18 | 15 |
| WMG-51 | 13 | 1 |
| WMG-59 | 2 | 9 |
| WZ-22 | 6 | 4 |
| WZ-32 | 101 | 102 |
| WZ-42 | 109 | 101 |
| WZ-44 | 104 | 102 |
| WZ-48 | 16 | 46 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD FIBER-COUNTS | TEM-CHRYS-EXTERNAL QA FIBER-COUNTS |
|---|---|---|
| WCD-1 | 96 | 65 |
| WCD-10 | 14 | 76 |
| WCD-14 | 8 | 76 |
| WD-27 | 2 | 69 |
| WD-31 | 101 | 129 |
| WD-36 | 103 | 73 |
| WD-49 | 101 | 86 |
| WD-54 | 103 | 57 |
| WD-60 | 107 | 95 |
| WD-62 | 312 | 69 |
| WD-69 | 134 | 82 |
| WD-72 | 210 | 91 |
| WG-31 | 67 | 106 |
| WG-43 | 0 | 72 |
| WG-48 | 10 | 31 |
| WG-55 | 4 | 14 |
| WG-61 | 26 | 46 |
| WG-67 | 34 | 83 |
| WG-75 | 0 | 33 |
| WMG-24 | 1 | 67 |
| WMG-30 | 11 | 14 |
| WMG-35 | 17 | 31 |
| WMG-38 | 5 | 68 |
| WMG-55 | 22 | 21 |
| WMG-57 | 20 | 80 |
| WMG-59 | 2 | 21 |
| WZ-23 | 0 | 34 |
| WZ-27 | 103 | 94 |
| WZ-34 | 48 | 92 |
| WZ-38 | 111 | 75 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| | TEM-CHRYS-STANDARD FIBERS - PER M**3 | TEM-CHRYS-DUPLICATE FIBERS - PER M**3 |
|---|---|---|
| FILTER ID | | |
| WD-27 | 3000 | 4000 |
| WD-38 | 62000 | 280000 |
| WD-47 | 160000 | 220000 |
| WD-56 | 1110000 | 1140000 |
| WD-57 | 2420000 | 1360000 |
| WD-60 | 204000 | 310000 |
| WD-70 | 10200000 | 9820000 |
| WD-71 | 2850000 | 4080000 |
| WG-27 | 83400000 | 1430000000 |
| WG-35 | 43000 | 45000 |
| WG-40 | 20000 | 5000 |
| WG-54 | 100000 | 100000 |
| WG-69 | 590000 | 1200000 |
| WG-72 | 500000 | 200000 |
| WMG-23 | 47000 | 47000 |
| WMG-33 | 24000 | 6000 |
| WMG-43 | 7000 | 16000 |
| WMG-50 | 0 | 10000 |
| WMG-53 | 1000 | 0 |
| WZ-22 | 8000 | 4000 |
| WZ-30 | 63000 | 171000 |
| WZ-36 | 1550000 | 1050000 |
| WZ-40 | 28000 | 28000 |
| WZ-41 | 23000 | 36000 |
| WZ-45 | 150000 | 184000 |
| WZ-48 | 26000 | 110000 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD FIBERS - PER M**3 | TEM-CHRYS-REPLICATE FIBERS - PER M**3 |
|---|---|---|
| WCD-13 | 1000 | 10000 |
| WCD-2 | 88000 | 151000 |
| WCD-8 | 605000 | 210000 |
| WD-29 | 3270000 | 4380000 |
| WD-48 | 1140000 | 194000 |
| WD-66 | 58000 | 350000 |
| WD-68 | 8940000 | 5410000 |
| WD-69 | 1960000 | 5370000 |
| WG-38 | 22000 | 10000 |
| WG-50 | 260000 | 370000 |
| WG-57 | 100000 | 0 |
| WG-65 | 3100000 | 200000 |
| WMG-19 | 14000 | 17000 |
| WMG-31 | 60000 | 77000 |
| WMG-46 | 3000 | 4000 |
| WMG-49 | 28000 | 23000 |
| WMG-51 | 63000 | 1000 |
| WMG-59 | 3000 | 10000 |
| WZ-22 | 8000 | 5000 |
| WZ-32 | 1380000 | 1390000 |
| WZ-42 | 368000 | 178000 |
| WZ-44 | 1940000 | 381000 |
| WZ-48 | 26000 | 73000 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD FIBERS - PER M**3 | TEM-CHRYS-EXTERNAL QA FIBERS - PER M**3 |
|---|---|---|
| WCD-1 | 150000 | 260000 |
| WCD-10 | 17000 | 650000 |
| WCD-14 | 10000 | 210000 |
| WD-27 | 3000 | 250000 |
| WD-31 | 2640000 | 38900000 |
| WD-36 | 783000 | 6700000 |
| WD-49 | 2160000 | 8000000 |
| WD-54 | 2870000 | 11000000 |
| WD-60 | 204000 | 3000000 |
| WD-62 | 4140000 | 12000000 |
| WD-69 | 1960000 | 15000000 |
| WD-72 | 10500000 | 40000000 |
| WG-31 | 110000 | 576000 |
| WG-43 | 0 | 220000 |
| WG-48 | 260000 | 4300000 |
| WG-55 | 200000 | 2700000 |
| WG-61 | 770000 | 1700000 |
| WG-67 | 1700000 | 7100000 |
| WG-75 | 0 | 67000 |
| WMG-24 | 1000 | 180000 |
| WMG-30 | 15000 | 19000 |
| WMG-35 | 23000 | 42000 |
| WMG-38 | 7000 | 120000 |
| WMG-55 | 26000 | 25000 |
| WMG-57 | 27000 | 79000 |
| WMG-59 | 3000 | 36000 |
| WZ-23 | 0 | 46000 |
| WZ-27 | 164000 | 1900000 |
| WZ-34 | 64000 | 4600000 |
| WZ-38 | 457000 | 3700000 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| | TEM-CHRYS-STANDARD | TEM-CHRYS-DUPLICATE |
|---|---|---|
| | NG/M**3 | NG/M**3 |
| FILTER ID | | |
| WD-27 | 0.01 | 0.02 |
| WD-38 | 0.38 | 1.10 |
| WD-47 | 0.75 | 1.50 |
| WD-56 | 4.61 | 4.37 |
| WD-57 | 9.95 | 7.72 |
| WD-60 | 0.97 | 1.57 |
| WD-70 | 39.70 | 44.10 |
| WD-71 | 16.30 | 18.30 |
| WG-27 | 1680.00 | 15800.00 |
| WG-35 | 0.19 | 0.28 |
| WG-40 | 0.06 | 0.02 |
| WG-54 | 0.30 | 0.50 |
| WG-69 | 3.90 | 5.10 |
| WG-72 | 3.00 | 1.00 |
| WMG-23 | 0.22 | 0.16 |
| WMG-33 | 0.08 | 0.02 |
| WMG-43 | 0.03 | 0.08 |
| WMG-50 | 0.00 | 0.10 |
| WMG-53 | 0.01 | 0.00 |
| WZ-22 | 0.02 | 0.01 |
| WZ-30 | 0.36 | 0.75 |
| WZ-36 | 5.52 | 5.75 |
| WZ-40 | 0.11 | 0.12 |
| WZ-41 | 0.09 | 0.17 |
| WZ-45 | 0.88 | 0.84 |
| WZ-48 | 0.22 | 0.56 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD NG/M**3 | TEM-CHRYS-REPLICATE NG/M**3 |
|---|---|---|
| WCD-13 | 0.01 | 0.04 |
| WCD-2 | 0.42 | 0.68 |
| WCD-8 | 2.97 | 1.00 |
| WD-29 | 18.10 | 24.70 |
| WD-48 | 4.91 | 0.82 |
| WD-66 | 0.33 | 2.10 |
| WD-68 | 40.10 | 26.00 |
| WD-69 | 10.70 | 24.30 |
| WG-38 | 0.08 | 0.05 |
| WG-50 | 1.60 | 2.30 |
| WG-57 | 0.70 | 0.00 |
| WG-65 | 18.00 | 2.00 |
| WMG-19 | 0.07 | 0.07 |
| WMG-31 | 0.34 | 0.52 |
| WMG-46 | 0.01 | 0.01 |
| WMG-49 | 0.09 | 0.10 |
| WMG-51 | 0.68 | 0.00 |
| WMG-59 | 0.01 | 0.07 |
| WZ-22 | 0.02 | 0.03 |
| WZ-32 | 5.23 | 4.49 |
| WZ-42 | 1.49 | 0.98 |
| WZ-44 | 8.27 | 1.92 |
| WZ-48 | 0.22 | 0.56 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| FILTER ID | TEM-CHRYS-STANDARD NG/M**3 | TEM-CHRYS-EXTERNAL QA NG/M**3 |
|---|---|---|
| WCD-1 | 0.86 | 1.70 |
| WCD-10 | 0.11 | 4.00 |
| WCD-14 | 0.08 | 1.20 |
| WD-27 | 0.01 | 4.50 |
| WD-31 | 13.60 | 314.00 |
| WD-36 | 3.18 | 57.00 |
| WD-49 | 9.41 | 34.00 |
| WD-54 | 12.10 | 96.00 |
| WD-60 | 0.97 | 19.00 |
| WD-62 | 24.40 | 77.00 |
| WD-69 | 10.70 | 3200.00 |
| WD-72 | 62.00 | 190.00 |
| WG-31 | 0.53 | 4.85 |
| WG-43 | 0.00 | 2.20 |
| WG-48 | 3.50 | 51.00 |
| WG-55 | 0.60 | 44.00 |
| WG-61 | 5.40 | 12.00 |
| WG-67 | 9.40 | 51.00 |
| WG-75 | 0.00 | 0.50 |
| WMG-24 | 0.00 | 1.20 |
| WMG-30 | 0.12 | 0.06 |
| WMG-35 | 0.10 | 0.20 |
| WMG-38 | 0.02 | 0.50 |
| WMG-55 | 0.10 | 0.09 |
| WMG-57 | 0.19 | 1.00 |
| WMG-59 | 0.01 | 0.10 |
| WZ-23 | 0.00 | 1.00 |
| WZ-27 | 0.75 | 9.20 |
| WZ-34 | 0.36 | 25.00 |
| WZ-38 | 3.08 | 14.00 |

APPENDIX C-2 (Continued)

TEM QUALITY ASSURANCE DATA

| TYPE | SAMPLE NO. | TEM-CHRYS-FIBER-COUNTS BLANK-ANALYSIS | TEM-CHRYS-FIBERS-PER FILTER BLANK-ANALYSIS | TEM-CHRYS-NG/FILTER BLANK-ANALYSIS |
|---|---|---|---|---|
| FIELD BLANKS | WD-11 | 1 | 50000 | 0.30 |
| | WD-23 | 2 | 30000 | 0.08 |
| | WG-13 | 12 | 170000 | 0.53 |
| | WMG-17 | 7 | 100000 | 1.00 |
| | WZ-10 | 2 | 30000 | 0.20 |
| | WZ-14 | 0 | 0 | 0.00 |
| | WZ-17 | 0 | 0 | 0.00 |
| | WZ-5 | 7 | 100000 | 0.50 |
| LABORATORY BLANKS | WD-1 | 6 | 90000 | 0.30 |
| | WD-3 | 1 | 10000 | 0.09 |
| | WG-77 | 4 | 60000 | 0.40 |
| | WG-78 | 0 | 0 | 0.00 |
| | WZ-2 | 4 | 60000 | 0.30 |
| | WZ-3 | 6 | 90000 | 0.60 |

# APPENDIX C-3
# PLM RESULTS AND RELEASABILITY RATINGS

| SAMPLE | SCHOOL | SITE | LOCATION (1) | TYPE (2) | CHRY % | AMES % | OTH ASBESTOS | GLS WOOL | FIBS GLS | CELLULOSE | OTHER FIB | PERLITE | VERMICULITE | OTH N FIB | RELEASE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-6 | 1 | 19 | 1 | S | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 15 | 2 |
| WM-6 | 1 | 19 | 1 | R | 10 | 0 | 0 | 0 | 0 | < 1 | 0 | 70 | 0 | 20 | 3 |
| WM-7 | 1 | 21 | 1 | D | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 10 | 4 |
| WM-7 | 1 | 21 | 1 | S | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 0 | 15 | 5 |
| WM-8 | 1 | 18 | 1 | S | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 87 | 0 | 5 | 2 |
| WM-9 | 1 | 18 | 2 | D | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 15 | 3 |
| WM-9 | 1 | 18 | 2 | S | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 10 | 2 |
| WM-10 | 1 | 20 | 1 | R | 15 | 0 | 0 | 0 | 0 | < 1 | 0 | 75 | 0 | 10 | 4 |
| WM-10 | 1 | 20 | 1 | S | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 11 | 6 |
| WM-11 | 1 | 24 | 1 | D | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 10 | 3 |
| WM-11 | 1 | 24 | 1 | S | 10 | 0 | 0 | 0 | 0 | 1 | 0 | 79 | 0 | 10 | 2 |
| WM-12 | 1 | 22 | 1 | S | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 10 | 5 |
| WM-14 | 1 | 23 | 2 | S | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 87 | 0 | 3 | 5 |
| WM-14 | 1 | 23 | 2 | R | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 10 | 3 |
| WM-15 | 1 | 27 | 1 | D | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 0 | 10 | 4 |
| WM-15 | 1 | 27 | 1 | S | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 79 | 0 | 12 | 5 |
| WM-16 | 1 | 30 | 1 | S | 8 | 0 | 0 | <1 | 0 | 0 | 0 | 74 | 0 | 18 | 5 |
| WM-16 | 1 | 30 | 1 | R | 10 | 0 | 0 | 0 | 0 | 1 | 0 | 70 | 0 | 19 | 4 |
| WM-17 | 1 | 29 | 1 | R | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 15 | 4 |
| WM-17 | 1 | 29 | 1 | S | 8 | 0 | 0 | 0 | 0 | 5 | 0 | 70 | 0 | 17 | 4 |
| WM-18 | 1 | 31 | 1 | R | 15 | 0 | 0 | 0 | 0 | T | 0 | 60 | 0 | 25 | 3 |
| WM-18 | 1 | 31 | 1 | S | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 0 | 20 | 2 |
| WM-19 | 1 | 28 | 1 | D | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 10 | 4 |
| WM-19 | 1 | 28 | 1 | S | 11 | 0 | 0 | 0 | 0 | 2 | 0 | 80 | 0 | 7 | 5 |
| WM-20 | 1 | 26 | 1 | R | 20 | 0 | 0 | 0 | 0 | < 1 | 0 | 65 | 0 | 15 | 3 |
| WM-20 | 1 | 26 | 1 | S | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 82 | 0 | 10 | 2 |
| WM-21 | 1 | 25 | 1 | D | 25 | 0 | 0 | 0 | 0 | 1 | 0 | 44 | 0 | 30 | 4 |
| WM-21 | 1 | 25 | 1 | S | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 78 | 0 | 12 | 2 |
| WM-23 | 1 | 32 | 1 | D | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 74 | 0 | 5 | 3 |
| WM-23 | 1 | 32 | 1 | S | 7 | 0 | 0 | 0 | 0 | 2 | 0 | 81 | 0 | 10 | 2 |
| WM-24 | 1 | 33 | 1 | S | 3 | 0 | 0 | 0 | 0 | 5 | 0 | 85 | 0 | 7 | 3 |
| WM-26 | 1 | 35 | 2 | R | 20 | 0 | 0 | 0 | 0 | < 1 | 0 | 70 | 0 | 10 | 4 |
| WM-26 | 1 | 35 | 2 | S | 8 | 0 | 0 | 0 | 0 | 3 | 0 | 74 | 0 | 15 | 5 |
| WM-27 | 1 | 34 | 1 | D | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 20 | 4 |
| WM-27 | 1 | 34 | 1 | S | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 85 | 0 | 9 | 5 |
| WM-28 | 2 | 6 | 1 | S | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 89 | 0 | 6 | 2 |
| WM-29 | 2 | 7 | 1 | S | 6 | 0 | 0 | 0 | 0 | 3 | 0 | 86 | 0 | 5 | 2 |
| WM-30 | 2 | 8 | 1 | S | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 89 | 0 | 5 | 2 |
| WM-31 | 2 | 9 | 1 | S | 4 | 0 | 0 | 0 | 0 | < 1 | 0 | 90 | 0 | 6 | 2 |
| WM-33 | 2 | 10 | 1 | S | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 87 | 0 | 6 | 2 |
| WM-34 | 2 | 11 | 1 | S | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 5 | 2 |
| WM-35 | 2 | 12 | 1 | S | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 | 5 | 2 |
| WM-13 | 1 | 23 | 1 | S | 4 | 0 | 0 | 0 | 1 | 1 | 0 | 69 | 0 | 25 | 2 |
| WM-22 | 1 | 25 | 2 | S | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | 0 | 28 | 2 |
| WM-25 | 1 | 35 | 1 | S | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | 0 | 37 | 2 |
| WM-32 | 2 | 9 | 2 | S | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 62 | 0 | 31 | 3 |

(1) Location
1 = Single Sample
2 = Side-by-side

(2) Type
S = Standard
D = Duplicate
R = Replicate

# APPENDIX C-4
# PLM and RELEASABILITY QUALITY ASSURANCE DATA

## DUPLICATE ANALYSIS

| | CHRYSOTILE-VOLUME %-OPERATOR #1 | CHRYSOTILE-VOLUME %-OPERATOR #2 | RELEASABILITY RATING-OPERATOR #1 | RELEASABILITY RATING-OPERATOR #2 |
|---|---|---|---|---|
| | DATA | DATA | DATA | DATA |
| SAMPLE NO. | | | | |
| WM-11 | 30 | 10 | 3 | 2 |
| WM-15 | 30 | 9 | 4 | 5 |
| WM-19 | 25 | 11 | 4 | 5 |
| WM-21 | 25 | 10 | 4 | 2 |
| WM-23 | 20 | 7 | 3 | 2 |
| WM-27 | 20 | 6 | 4 | 5 |
| WM-7 | 25 | 10 | 4 | 5 |
| WM-9 | 25 | 10 | 3 | 2 |

## REPLICATE ANALYSIS

| | CHRYSOTILE-VOLUME %-OPERATOR #1 | CHRYSOTILE-VOLUME %-OPERATOR #2 | RELEASABILITY RATING-OPERATOR #1 | RELEASABILITY RATING-OPERATOR #2 |
|---|---|---|---|---|
| | DATA | DATA | DATA | DATA |
| SAMPLE NO. | | | | |
| WM-10 | 15 | 13 | 4 | 6 |
| WM-14 | 10 | 10 | 5 | 3 |
| WM-16 | 10 | 8 | 4 | 5 |
| WM-17 | 20 | 8 | 4 | 4 |
| WM-18 | 15 | 5 | 3 | 2 |
| WM-20 | 20 | 8 | 3 | 2 |
| WM-26 | 20 | 8 | 4 | 5 |
| WM-6 | 10 | 9 | 3 | 2 |

## EXTERNAL QA ANALYSIS

| | CHRYSOTILE-VOLUME %-INTERNAL | CHRYSOTILE-VOLUME %-EXTERNAL QA | RELEASABILITY RATING-INTERNAL | RELEASABILITY RATING-EXTERNAL QA |
|---|---|---|---|---|
| | DATA | DATA | DATA | DATA |
| SAMPLE NO. | | | | |
| WM-11 | 10.0 | 4 | 4.0 | 2 |
| WM-21 | 17.5 | 4 | 3.0 | 2 |
| WM-26 | 14.0 | 5 | 4.5 | 2 |
| WM-31 | 4.0 | 7 | 2.0 | 3 |

# APPENDIX D

## DATA LISTINGS

# APPENDIX D-1
## DATA LISTING FOR AIR SAMPLES
(Values are weighted averages when more than one analysis was done on each sample)

| PERIOD | SCHOOL | SITE | LOCATION (1) | FILTER ID | SITE TYPE (2) | #FIBERS | fib/m$^3$ | ng/m$^3$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | WD-1 | LB | 6 | 0.00E+00 | 0.00E+00 |
| 1 | 0 | 0 | 0 | WD-3 | LB | 1 | 0.00E+00 | 0.00E+00 |
| 1 | 1 | 1 | 1 | WD-29 | UA | 145 | 3.83E+06 | 2.14E+01 |
| 1 | 1 | 1 | 2 | WD-30 | UA | 373 | 4.02E+07 | 2.00E+02 |
| 1 | 1 | 2 | 1 | WD-33 | UA | 131 | 9.20E+05 | 4.66E+00 |
| 1 | 1 | 4 | 1 | WD-47 | UA | 37 | 1.90E+05 | 1.13E+00 |
| 1 | 1 | 4 | 2 | WD-48 | UA | 126 | 6.67E+05 | 2.87E+00 |
| 1 | 1 | 4 | 3 | WD-49 | UA | 101 | 2.18E+06 | 9.41E+00 |
| 1 | 1 | 5 | 1 | WD-63 | UA | 111 | 1.81E+06 | 7.10E+00 |
| 1 | 1 | 5 | 3 | WD-62 | UA | 312 | 4.14E+06 | 2.44E+01 |
| 1 | 1 | 6 | 2 | WD-59 | UA | 132 | 3.52E+06 | 1.51E+01 |
| 1 | 1 | 6 | 3 | WD-57 | UA | 120 | 1.89E+06 | 8.84E+00 |
| 1 | 1 | 7 | 1 | WD-38 | UA | 34 | 1.81E+05 | 7.40E-01 |
| 1 | 1 | 8 | 2 | WD-36 | UA | 103 | 7.83E+05 | 3.18E+00 |
| 1 | 1 | 9 | 2 | WD-54 | UA | 103 | 2.87E+06 | 1.21E+01 |
| 1 | 1 | 10 | 1 | WD-50 | UA | 54 | 2.80E+05 | 1.60E+00 |
| 1 | 1 | 11 | 0 | WD-23 | FB | 2 | 0.00E+00 | 0.00E+00 |
| 1 | 1 | 11 | 2 | WD-43 | PA | 52 | 8.10E+04 | 3.30E-01 |
| 1 | 1 | 12 | 1 | WD-31 | PA | 101 | 2.64E+06 | 1.38E+01 |
| 1 | 1 | 13 | 2 | WD-58 | PA | 148 | 1.13E+06 | 4.49E+00 |
| 1 | 1 | 14 | 1 | WD-60 | NA | 123 | 2.57E+05 | 1.27E+00 |
| 1 | 1 | 15 | 1 | WD-40 | NA | 54 | 3.00E+05 | 1.10E+00 |
| 1 | 1 | 16 | 2 | WD-66 | NA | 51 | 2.04E+05 | 1.22E+00 |
| 1 | 1 | 17 | 2 | WD-27 | 0 | 3 | 3.50E+03 | 1.45E-02 |
| 1 | 2 | 1 | 0 | WD-11 | FB | 1 | 0.00E+00 | 0.00E+00 |
| 1 | 2 | 1 | 2 | WD-74 | PA | 123 | 9.38E+05 | 8.69E+00 |
| 1 | 2 | 2 | 1 | WD-67 | PA | 124 | 6.09E+06 | 3.25E+01 |
| 1 | 2 | 2 | 2 | WD-68 | PA | 270 | 7.18E+06 | 3.31E+01 |
| 1 | 2 | 3 | 1 | WD-69 | PA | 120 | 3.67E+06 | 1.75E+01 |
| 1 | 2 | 3 | 2 | WD-70 | PA | 103 | 1.00E+07 | 4.19E+01 |
| 1 | 2 | 4 | 1 | WD-71 | PA | 147 | 3.47E+06 | 1.73E+01 |
| 1 | 2 | 4 | 2 | WD-72 | PA | 210 | 1.05E+07 | 6.20E+01 |
| 2 | 0 | 0 | 0 | WG-77 | LB | 4 | 0.00E+00 | 0.00E+00 |
| 2 | 0 | 0 | 0 | WG-78 | LB | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 3 | 1 | WG-54 | IB | 2 | 1.00E+05 | 4.00E-01 |
| 2 | 1 | 3 | 2 | WG-55 | IB | 4 | 2.00E+05 | 6.00E-01 |
| 2 | 1 | 3 | 3 | WG-53 | IB | 4 | 2.00E+05 | 2.00E+00 |
| 2 | 1 | 4 | 2 | WG-52 | IB | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 4 | 3 | WG-50 | IB | 29 | 3.15E+05 | 1.95E+00 |
| 2 | 1 | 9 | 2 | WG-72 | IB | 7 | 3.50E+05 | 2.00E+00 |
| 2 | 1 | 9 | 3 | WG-70 | IB | 14 | 7.70E+05 | 5.00E+00 |
| 2 | 1 | 10 | 1 | WG-67 | IB | 34 | 1.70E+06 | 9.40E+00 |
| 2 | 1 | 10 | 3 | WG-69 | IB | 22 | 8.95E+05 | 4.50E+00 |
| 2 | 1 | 14 | 2 | WG-43 | NA | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 15 | 2 | WG-45 | NA | 8 | 1.00E+04 | 4.00E-02 |
| 2 | 1 | 16 | 1 | WG-40 | NA | 8 | 1.25E+04 | 4.00E-02 |
| 2 | 1 | 17 | 2 | WG-75 | 0 | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 18 | 1 | WG-48 | IB | 10 | 2.60E+05 | 3.50E+00 |
| 2 | 1 | 18 | 3 | WG-47 | IB | 4 | 4.00E+05 | 2.00E+00 |
| 2 | 1 | 19 | 1 | WG-57 | IB | 2 | 5.00E+04 | 3.50E-01 |
| 2 | 1 | 19 | 3 | WG-56 | IB | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 20 | 2 | WG-65 | IB | 18 | 1.85E+06 | 1.00E+01 |
| 2 | 1 | 20 | 3 | WG-63 | IB | 3 | 3.00E+05 | 2.00E+00 |
| 2 | 1 | 21 | 1 | WG-59 | IB | 2 | 3.00E+05 | 1.00E+00 |
| 2 | 1 | 21 | 3 | WG-61 | IB | 26 | 7.70E+05 | 5.40E+00 |
| 2 | 1 | 22 | 0 | WG-13 | FB | 12 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 22 | 1 | WG-28 | UA | 117 | 1.45E+06 | 8.29E+00 |
| 2 | 1 | 22 | 2 | WG-29 | UA | 23 | 4.00E+04 | 3.70E-01 |
| 2 | 1 | 23 | 1 | WG-38 | UA | 11 | 1.60E+04 | 6.50E-02 |
| 2 | 1 | 23 | 2 | WG-39 | UA | 84 | 1.30E+05 | 7.80E-01 |
| 2 | 1 | 24 | 2 | WG-31 | UA | 67 | 1.10E+05 | 5.30E-01 |
| 2 | 1 | 25 | 1 | WG-32 | UA | 50 | 8.20E+04 | 5.60E-01 |

(1) Location
1 = Single Sample
2 = Side-by-side

(2) Type
S = Standard
D = Duplicate
R = Replicate

| PERIOD | SCHOOL | SITE | LOCATION (1) | FILTER ID | SITE TYPE (2) | #FIBERS | fib/m$^3$ | ng/m$^3$ |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 26 | 2 | WG-35 | UA | 28 | 4.40E+04 | 2.35E-01 |
| 2 | 1 | 27 | 2 | WG-37 | UA | 68 | 1.20E+05 | 7.00E-01 |
| 2 | 1 | 90 | 1 | WG-24 | MP | 27 | 4.70E+07 | 3.90E+02 |
| 2 | 1 | 90 | 2 | WG-25 | MP | 36 | 6.30E+07 | 3.80E+02 |
| 2 | 1 | 91 | 1 | WG-26 | MP | 3 | 4.00E+06 | 4.00E+01 |
| 2 | 1 | 91 | 2 | WG-27 | MP | 109 | 7.57E+08 | 8.74E+03 |
| 2 | 1 | 92 | 1 | WG-1 | PP | 15 | 6.00E+08 | 1.30E+04 |
| 2 | 1 | 93 | 1 | WG-2 | PP | 4 | 3.00E+08 | 1.00E+03 |
| 2 | 1 | 94 | 1 | WG-11 | PP | 10 | 4.40E+08 | 2.30E+03 |
| 2 | 1 | 95 | 1 | WG-12 | PP | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 96 | 1 | WG-22 | PP | 0 | 0.00E+00 | 0.00E+00 |
| 2 | 1 | 97 | 1 | WG-23 | PP | 20 | 1.80E+08 | 1.70E+03 |
| 3 | 1 | 1 | 1 | WMG-24 | UA | 1 | 1.00E+03 | 3.00E-03 |
| 3 | 1 | 1 | 3 | WMG-26 | UA | 4 | 5.00E+03 | 2.00E-02 |
| 3 | 1 | 2 | 2 | WMG-40 | UA | 16 | 2.20E+04 | 9.30E-02 |
| 3 | 1 | 3 | 2 | WMG-46 | UA | 3 | 3.50E+03 | 9.50E-03 |
| 3 | 1 | 3 | 3 | WMG-47 | UA | 3 | 4.00E+03 | 2.00E-02 |
| 3 | 1 | 4 | 1 | WMG-51 | UA | 7 | 3.20E+04 | 3.43E-01 |
| 3 | 1 | 4 | 3 | WMG-50 | UA | 5 | 5.00E+03 | 5.00E-02 |
| 3 | 1 | 5 | 0 | WMG-17 | FB | 7 | 0.00E+00 | 0.00E+00 |
| 3 | 1 | 5 | 1 | WMG-33 | UA | 10 | 1.50E+04 | 5.20E-02 |
| 3 | 1 | 5 | 3 | WMG-32 | UA | 0 | 0.00E+00 | 0.00E+00 |
| 3 | 1 | 6 | 2 | WMG-30 | UA | 11 | 1.50E+04 | 1.20E-01 |
| 3 | 1 | 6 | 3 | WMG-31 | UA | 55 | 6.85E+04 | 4.30E-01 |
| 3 | 1 | 7 | 1 | WMG-19 | UA | 12 | 1.55E+04 | 6.85E-02 |
| 3 | 1 | 7 | 2 | WMG-20 | UA | 29 | 3.70E+04 | 2.00E-01 |
| 3 | 1 | 8 | 1 | WMG-22 | UA | 2 | 3.00E+03 | 1.00E-02 |
| 3 | 1 | 8 | 2 | WMG-23 | UA | 37 | 4.70E+04 | 1.90E-01 |
| 3 | 1 | 8 | 3 | WMG-21 | UA | 8 | 9.00E+03 | 6.00E-02 |
| 3 | 1 | 9 | 1 | WMG-53 | UA | 1 | 5.00E+02 | 3.50E-03 |
| 3 | 1 | 9 | 3 | WMG-55 | UA | 22 | 2.60E+04 | 9.90E-02 |
| 3 | 1 | 10 | 2 | WMG-57 | UA | 20 | 2.70E+04 | 1.90E-01 |
| 3 | 1 | 11 | 2 | WMG-49 | PA | 17 | 2.55E+04 | 9.60E-02 |
| 3 | 1 | 12 | 1 | WMG-27 | PA | 0 | 0.00E+00 | 0.00E+00 |
| 3 | 1 | 13 | 1 | WMG-35 | PA | 17 | 2.30E+04 | 9.70E-02 |
| 3 | 1 | 14 | 2 | WMG-38 | NA | 5 | 7.00E+03 | 2.00E-02 |
| 3 | 1 | 15 | 2 | WMG-42 | NA | 9 | 1.00E+04 | 7.00E-02 |
| 3 | 1 | 16 | 1 | WMG-43 | NA | 9 | 1.15E+04 | 5.40E-02 |
| 3 | 1 | 17 | 2 | WMG-59 | 0 | 6 | 6.50E+03 | 4.00E-02 |
| 4 | 0 | 0 | 0 | WZ-2 | LB | 4 | 0.00E+00 | 0.00E+00 |
| 4 | 0 | 0 | 0 | WZ-3 | LB | 6 | 0.00E+00 | 0.00E+00 |
| 4 | 1 | 1 | 1 | WZ-27 | UA | 103 | 1.64E+05 | 7.46E-01 |
| 4 | 1 | 1 | 3 | WZ-26 | UA | 108 | 1.61E+06 | 6.67E+00 |
| 4 | 1 | 2 | 1 | WCD-1 | UA | 96 | 1.50E+05 | 8.60E-01 |
| 4 | 1 | 2 | 2 | WCD-2 | UA | 83 | 1.20E+05 | 5.51E-01 |
| 4 | 1 | 3 | 1 | WCD-8 | UA | 117 | 4.08E+05 | 1.99E+00 |
| 4 | 1 | 3 | 2 | WCD-9 | UA | 104 | 5.07E+05 | 2.87E+00 |
| 4 | 1 | 3 | 3 | WCD-10 | UA | 14 | 1.70E+04 | 1.10E-01 |
| 4 | 1 | 4 | 1 | WZ-32 | UA | 102 | 1.39E+06 | 4.86E+00 |
| 4 | 1 | 4 | 2 | WZ-33 | UA | 133 | 8.65E+05 | 4.03E+00 |
| 4 | 1 | 5 | 1 | WZ-45 | UA | 95 | 1.67E+05 | 8.59E-01 |
| 4 | 1 | 5 | 2 | WZ-44 | UA | 103 | 1.16E+06 | 5.10E+00 |
| 4 | 1 | 5 | 3 | WZ-43 | UA | 101 | 2.78E+05 | 1.37E+00 |
| 4 | 1 | 6 | 1 | WZ-47 | UA | 1 | 1.00E+03 | 6.00E-03 |
| 4 | 1 | 6 | 2 | WZ-48 | UA | 45 | 6.97E+04 | 4.47E-01 |
| 4 | 1 | 7 | 0 | WZ-17 | FB | 0 | 0.00E+00 | 0.00E+00 |
| 4 | 1 | 7 | 2 | WZ-30 | UA | 76 | 1.17E+05 | 5.53E-01 |
| 4 | 1 | 8 | 1 | WCD-5 | UA | 7 | 7.00E+04 | 1.00E-01 |
| 4 | 1 | 8 | 2 | WCD-6 | UA | 15 | 7.40E+04 | 4.30E-01 |
| 4 | 1 | 9 | 1 | WZ-37 | UA | 80 | 1.10E+05 | 4.60E-01 |
| 4 | 1 | 9 | 2 | WZ-38 | UA | 111 | 4.57E+05 | 3.08E+00 |
| 4 | 1 | 9 | 3 | WZ-38 | UA | 148 | 1.30E+06 | 5.64E+00 |

(1) Location
1 = Single Sample
2 = Side-by-side

(2) Type
S = Standard
D = Duplicate
R = Replicate

| PERIOD | SCHOOL | SITE | LOCATION (1) | FILTER ID | SITE TYPE (2) | #FIBERS | fib/m$^3$ | ng/m$^3$ |
|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 11 | 1 | WZ-34 | PA | 48 | 6.40E+04 | 3.60E-01 |
| 4 | 1 | 11 | 2 | WZ-35 | PA | 127 | 3.99E+05 | 1.71E+00 |
| 4 | 1 | 12 | 0 | WZ-5 | FB | 7 | 0.00E+00 | 0.00E+00 |
| 4 | 1 | 13 | 1 | WZ-41 | PA | 22 | 2.95E+04 | 1.33E-01 |
| 4 | 1 | 13 | 2 | WZ-42 | PA | 105 | 2.73E+05 | 1.23E+00 |
| 4 | 1 | 14 | 1 | WCD-13 | NA | 5 | 5.50E+03 | 2.50E-02 |
| 4 | 1 | 14 | 2 | WCD-14 | NA | 8 | 1.00E+04 | 8.00E-02 |
| 4 | 1 | 15 | 1 | WCD-3 | NA | 82 | 1.20E+05 | 5.10E-01 |
| 4 | 1 | 15 | 2 | WCD-4 | NA | 46 | 6.90E+04 | 3.00E-01 |
| 4 | 1 | 16 | 0 | WZ-10 | FB | 2 | 0.00E+00 | 0.00E+00 |
| 4 | 1 | 16 | 1 | WZ-39 | NA | 35 | 5.10E+04 | 2.00E-01 |
| 4 | 1 | 16 | 2 | WZ-40 | NA | 19 | 2.80E+04 | 1.15E-01 |
| 4 | 1 | 17 | 0 | WZ-14 | FB | 0 | 0.00E+00 | 0.00E+00 |
| 4 | 1 | 17 | 1 | WZ-22 | 0 | 4 | 5.67E+03 | 2.00E-02 |
| 4 | 1 | 17 | 2 | WZ-23 | 0 | 0 | 0.00E+00 | 0.00E+00 |

(1) Location
1 = Single Sample
2 = Side-by-side

(2) Type
S = Standard
D = Duplicate
R = Replicate

# APPENDIX D-2
## DATA LISTING OF PLM RESULTS
(Values are weighted averages when more than one analysis was done on a sample)

| OBS | SCHOOL | SITE | LOC (1) | CHRYSO-TILE % | RELEASEA-BILITY |
|---|---|---|---|---|---|
| 1 | 1 | 118 | 1 | 8.0 | 2.0 |
| 2 | 1 | 118 | 2 | 17.5 | 2.5 |
| 3 | 1 | 119 | 1 | 9.5 | 2.5 |
| 4 | 1 | 120 | 1 | 14.0 | 5.0 |
| 5 | 1 | 121 | 1 | 17.5 | 4.5 |
| 6 | 1 | 122 | 1 | 6.0 | 5.0 |
| 7 | 1 | 123 | 1 | 4.0 | 2.0 |
| 8 | 1 | 123 | 2 | 10.0 | 4.0 |
| 9 | 1 | 124 | 1 | 20.0 | 2.5 |
| 10 | 1 | 125 | 1 | 17.5 | 3.0 |
| 11 | 1 | 125 | 2 | 4.0 | 2.0 |
| 12 | 1 | 126 | 1 | 14.0 | 2.5 |
| 13 | 1 | 127 | 1 | 19.5 | 4.5 |
| 14 | 1 | 128 | 1 | 18.0 | 4.5 |
| 15 | 1 | 129 | 1 | 14.0 | 4.0 |
| 16 | 1 | 130 | 1 | 9.0 | 4.5 |
| 17 | 1 | 131 | 1 | 10.0 | 2.5 |
| 18 | 1 | 132 | 1 | 13.5 | 2.5 |
| 19 | 1 | 133 | 1 | 3.0 | 3.0 |
| 20 | 1 | 134 | 1 | 13.0 | 4.5 |
| 21 | 1 | 135 | 1 | 5.0 | 2.0 |
| 22 | 1 | 135 | 2 | 14.0 | 4.5 |
| 23 | 2 | 6 | 1 | 5.0 | 2.0 |
| 24 | 2 | 7 | 1 | 6.0 | 2.0 |
| 25 | 2 | 8 | 1 | 6.0 | 2.0 |
| 26 | 2 | 9 | 1 | 4.0 | 2.0 |
| 27 | 2 | 9 | 2 | 7.0 | 3.0 |
| 28 | 2 | 10 | 1 | 7.0 | 2.0 |
| 29 | 2 | 11 | 1 | 11.0 | 2.0 |
| 30 | 2 | 12 | 1 | 11.0 | 2.0 |

(1) Location
1 = Standard sample
2 = Side-by-side sample

# APPENDIX E

## SUMMARY OF SAMPLE RESULTS FOR EACH SCHOOL AND SITE

Table E.1 Chrysotile fiber concentration ($f/m^3$) and mass concentration ($ng/m^3$) at each site at School 1. During encapsulation "Unpainted Asbestos" sites were located immediately outside the barriers.

| | | PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BEFORE ENCAPSULATION | | DURING ENCAPSULATION | | IMMEDIATELY AFTER ENCAPSULATION | | AFTER SCHOOL RESUMED | |
| | | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
| | | TEM | TEM | TEM | TEM | TEM | TEM | TEM | TEM |
| CODE | SITE | | | | | | | | |
| UNPAINTED ASBESTOS | 1 | 22000.0 | 111.0 | . | . | 3.0 | 0.0 | 887.0 | 3.7 |
| | 2 | 920.0 | 4.7 | . | . | 22.0 | 0.1 | 135.0 | 0.7 |
| | 3 | . | . | . | . | 3.8 | 0.0 | 237.0 | 1.3 |
| | 4 | 1290.0 | 5.7 | . | . | 18.5 | 0.2 | 1130.0 | 4.5 |
| | 5 | 2980.0 | 15.8 | . | . | 7.5 | 0.0 | 471.0 | 2.2 |
| | 6 | 2710.0 | 12.0 | . | . | 41.8 | 0.3 | 35.4 | 0.2 |
| | 7 | 181.0 | 0.7 | . | . | 26.3 | 0.1 | 117.0 | 0.6 |
| | 8 | 783.0 | 3.2 | . | . | 17.0 | 0.1 | 72.0 | 0.3 |
| | 9 | 2870.0 | 12.1 | . | . | 13.3 | 0.1 | 792.0 | 3.7 |
| | 10 | 280.0 | 1.6 | . | . | 27.0 | 0.2 | . | . |
| | 22 | . | . | 745.0 | 3.3 | . | . | . | . |
| | 23 | . | . | 73.0 | 0.4 | . | . | . | . |
| | 24 | . | . | 110.0 | 0.5 | . | . | . | . |
| | 25 | . | . | 82.0 | 0.6 | . | . | . | . |
| | 26 | . | . | 44.0 | 0.2 | . | . | . | . |
| | 27 | . | . | 120.0 | 0.7 | . | . | . | . |
| PAINTED ASBESTOS | 11 | 81.0 | 0.3 | . | . | 25.5 | 0.1 | 232.0 | 1.0 |
| | 12 | 2640.0 | 13.6 | . | . | 0.0 | 0.0 | . | . |
| | 13 | 1130.0 | 4.5 | . | . | 23.0 | 0.1 | 151.0 | 0.7 |
| NON-ASBESTOS | 14 | 257.0 | 1.3 | 0.0 | 0.0 | 7.0 | 0.0 | 7.8 | 0.1 |
| | 15 | 300.0 | 1.1 | 10.0 | 0.0 | 10.0 | 0.1 | 94.5 | 0.4 |
| | 16 | 204.0 | 1.2 | 12.5 | 0.0 | 11.5 | 0.1 | 39.5 | 0.2 |

TABLE E.1 (Continued)

| | | PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BEFORE ENCAPSULATION | | DURING ENCAPSULATION | | IMMEDIATELY AFTER ENCAPSULATION | | AFTER SCHOOL RESUMED | |
| | | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 | FIBERS/M**3 (THOUSANDS) | NG/M**3 |
| | | TEM | TEM | TEM | TEM | TEM | TEM | TEM | TEM |
| CODE | SITE | | | | | | | | |
| INSIDE BARRIER | 3 | . | . | 150.0 | 0.5 | . | . | . | . |
| | 4 | . | . | 0.0 | 0.0 | . | . | . | . |
| | 9 | . | . | 350.0 | 2.0 | . | . | . | . |
| | 10 | . | . | 1700.0 | 9.4 | . | . | . | . |
| | 18 | . | . | 260.0 | 3.5 | . | . | . | . |
| | 19 | . | . | 50.0 | 0.4 | . | . | . | . |
| | 20 | . | . | 1650.0 | 10.0 | . | . | . | . |
| | 21 | . | . | 300.0 | 1.0 | . | . | . | . |
| OUTDOOR | 17 | 3.5 | 0.0 | 0.0 | 0.0 | 6.5 | 0.0 | 2.8 | 0.0 |

Table E.2 Percentage chrysotile content and releasibility for each school and site.

| | | CHRYSOTILE % | RELEASABILITY |
|---|---|---|---|
| | | MEAN | MEAN |
| SCHOOL | SITE | | |
| 1 | 118 | 12.75 | 2.25 |
| | 119 | 9.50 | 2.50 |
| | 120 | 14.00 | 5.00 |
| | 121 | 17.50 | 4.50 |
| | 122 | 6.00 | 5.00 |
| | 123 | 7.00 | 3.00 |
| | 124 | 20.00 | 2.50 |
| | 125 | 10.75 | 2.50 |
| | 126 | 14.00 | 2.50 |
| | 127 | 19.50 | 4.50 |
| | 128 | 18.00 | 4.50 |
| | 129 | 14.00 | 4.00 |
| | 130 | 9.00 | 4.50 |
| | 131 | 10.00 | 2.50 |
| | 132 | 13.50 | 2.50 |
| | 133 | 3.00 | 3.00 |
| | 134 | 13.00 | 4.50 |
| | 135 | 9.50 | 3.25 |
| 2 | 6 | 5.00 | 2.00 |
| | 7 | 6.00 | 2.00 |
| | 8 | 6.00 | 2.00 |
| | 9 | 5.50 | 2.50 |
| | 10 | 7.00 | 2.00 |
| | 11 | 11.00 | 2.00 |
| | 12 | 11.00 | 2.00 |

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Phase 2: Encapsulation with Latex Paint

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**15. Supplementary Notes**

**16. Abstract (Limit: 200 words)** Airborne asbestos levels were measured by transmission electron microscopy (TEM) before, during and after encapsulation of asbestos-containing material with latex paint in a suburban junior high school. The ceilings of the school were covered with a sprayed-on material containing chrysotile asbestos. Air samples were collected at four types of sites: indoor sites with unpainted asbestos material scheduled for painting, indoor sites with asbestos material which had been painted 16 months prior to the study, indoor sites with no asbestos material, and outdoor sites on the roof of the building. Bulk samples were collected prior to painting and analyzed by polarized light microscopy (PLM) to characterize the asbestos-containing material.

Airborne asbestos levels of up to 13,000 ng/m$^3$ were measured within the work site during painting. These results emphasize the need for worker respiratory protection and for containment barriers to prevent contamination of the rest of the building. Airborne asbestos levels were highest before encapsulation (up to 111 ng/m$^3$) and lowest immediately after encapsulation (<0.5 ng/m$^3$). After school resumed there was a small, but statistically significant, increase in airborne asbestos levels (up to 4.5 ng/m$^3$).

**17. Document Analysis a. Descriptors**
Airborne asbestos levels, asbestos, asbestos abatement, asbestos in schools, encapsulation, latex paint, PLM, TEM.

**b. Identifiers/Open-Ended Terms**

**c. COSATI Field/Group**

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