United States
Environmental Protection
Agency

Risk Reduction
Engineering Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-89/010 Aug. 1989

EPA

Project Summary

Evaluation of Asbestos Levels in Two Schools Before and After Asbestos Removal

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This report presents a statistical evaluation of airborne asbestos data collected at two schools before and after removal of asbestos-containing material (ACM). Although the monitoring data are not totally consistent with new Asbestos Hazard Emergency Response Act (AHERA) requirements and recent EPA guidelines, this study evaluates these historical data by standard statistical methods to determine if abated work areas met clearance criteria.

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

Introduction

The U.S. Environmental Protection Agency (EPA) has undertaken a variety of technical assistance and regulatory activities designed to control ACM in buildings and to minimize inhalation of asbestos fibers. In 1979, the EPA began publishing state-of-the-art guidance to help school administrators and building owners identify and control asbestos hazards in buildings. An important objective of these guidance documents has been to address the question of how to determine when an asbestos-abatement worksite has been successfully cleaned and is acceptable for reoccupancy.

The EPA's second asbestos guidance document, "Guidance for Controlling Friable Asbestos-Containing Materials in Buildings" (Blue Book) (EPA-560/5-83-002), describes for the first time a two-part process for determining when an abatement project is complete and the contractor can be released. The two steps are (1) a visual test to determine if the ACM has been properly abated and the worksite is free of debris and dust, and (2) an air test to determine if residual asbestos fibers generated during removal have been reduced below a predetermined level. The recommended method of sampling and analysis of air samples presented in the 1983 EPA guidance document was the National Institute for Occupational Safety and Health (NIOSH) method based on phase-contrast microscopy (PCM). The sampling and analysis specifications suggested for air monitoring after project completion included no mention of aggressive sampling and recommended the PCM detection limit as the criterion level for clearance. The limitations of PCM analysis and static sampling techniques for post-abatement clearance testing are now well known and have led to the use of more sophisticated and accurate methods of asbestos identification.

The EPA guidance document, "Guidance for Controlling Asbestos-Containing Materials in Buildings" (EPA-560/5-85-024) was published in June 1985. Later in 1985, EPA published "Measuring Airborne Asbestos Following An Abatement Action" (EPA-600/4-85-049), which discusses the subject in more detail. These documents recommended and presented supportive arguments for the use of aggressive sampling and transmission electron microscopic (TEM) analysis of air samples. In addition, these more recent guidelines contain a recommended protocol for aggressive sampling, a sampling strategy for post-abatement clearance monitoring, and a statistical method for evaluating the TEM results and the adequacy of the contractor's cleanup.

Sampling, analytical, and statistical protocols for clearance testing of an abatement site have undergone further revisions as a result of the Asbestos Hazard Emergency Response Act of 1986 (AHERA). The final rule (40 CFR Part 763, Subpart E), which was published October 30, 1987, specifies a detailed aggressive sampling protocol that incorporates the use of a leaf blower and fans, the collection and TEM analysis of a representative and statistically defensible number of air samples from inside and outside the work area, a statistical method (Z-test) for evaluating the TEM results, and numerous mandatory quality control and quality assurance procedures.

This report compares historical TEM air monitoring data collected in two schools (under static and aggressive conditions) before and after asbestos removal. To the extent that the data allow, this study attempts to evaluate these data by applying standard statistical methods designed to determine whether the inside airborne asbestos concentrations are significantly higher than the outside asbestos concentrations.

Study Design, Experimental Methods, and Site Descriptions

During the summer of 1985, air samples were collected on 0.8-µm pore size, 37-mm mixed diameter cellulose ester filters at two schools before and after ACM. During each sampling period, samples were first taken without any deliberate attempt to disturb the air (static sampling). A second set of samples was then taken after leaf blowers and fans had been used to resuspend any settled asbestos fibers (aggressive sampling). Each abatement work area at both schools had an aggressive clearance concentration of less than 0.01 fiber/cm^3 (by PCM) of air before the work area was cleared by PCM and before subsequent TEM air analyses were performed.

Six sites (rooms) were sampled at School 1, and four sites were sampled at School 2. Three air samples, each consisting of approximately 1,450 L, were collected at each site. The flow rate was approximately 3 L/min. Outdoor samples were collected on the roof of each school—16 at School 1 (6 before removal and 10 after removal) and 10 at School 2 (4 before removal and 6 after removal). Field blanks (filters handled that are subject to the same as standard samples, but through which no air is drawn) were used at both schools (13 at School 1 and 11 at School 2) to check for sources of asbestos contamination other than the air being sampled.

The samples were prepared in accordance with the NIOSH 7402 technique, which is a direct-preparation technique for cellulose ester membrane filters. Samples were analyzed by TEM in accordance with the procedures in Yamate *et al*. The results are expressed in asbestos structures per cubic centimeter (s/cm^3) for air samples and asbestos structures per square millimeter (s/mm^2) for blanks. When more than one analysis was done on a single filter, the average of the multiple readings was used in the statistical analysis. Results are not available for two samples from School 1, and one sample from School 2 was not analyzed because there was no filter in the cassette when it reached the laboratory. Statistical analyses are based on 99 TEM results from School 1 and 68 from School 2.

Methods of Statistical Analysis

Asbestos concentrations on the blank filters were examined first to ensure that a contamination problem did not exist before proceeding with the analysis of the field samples. Samples with an asbestos count of zero were assigned an estimated airborne asbestos concentration of zero s/cm^3. A concentration of zero was used in all subsequent calculations and analyses with the exception of the Z-test.

Some researchers set the airborne asbestos concentration to the analytical sensitivity when the structure count is zero. (The analytical sensitivity, also referred to as the detection limit, is the estimated airborne asbestos concentration calculated when a single fiber is counted in a sample.) In this research study, which involved statistical analysis of multiple samples, using the estimate of zero is preferable to substituting the analytical sensitivity because the latt approach introduces a positive bias th may obscure trends of interest.

Objectives

The objectives of this evaluation wer (1) To compare airborne asbestos leve after removal with outdoor levels, (2) T compare airborne asbestos levels befo and after removal, (3) To compare tw methods of sampling airborne asbesto static sampling and aggressive samplinc

Statistical analyses were designed address each of the three research obje tives. Summary statistics (mean an standard deviation) were generated f each sampling period, sampling metho and site.

Comparison of Airborne Asbestos Levels After Removal With Outdoor Levels

The Kruskal-Wallis one-way analysis variance and the Z-test were used to te for differences between indoor and ou door sites after asbestos removal. Th Kruskal-Wallis analysis is a nonpar metric test that uses ranks rather th actual data values. Although it is not definitive as the standard analysis variance, it does not require assumptior about the distribution of the data.

The Z-test is a standard comparison means for data that are normall distributed. Because it is based on a lo transformation of the data, the particul form of the Z-test required under th AHERA EPA Asbestos-Containing Mat rials in Schools, Final Rule and Notic specifies that zero concentrations are be replaced by the analytical sensitivit before calculating the Z statistic. A noted earlier, this is the only situation which the analytical sensitivity was use in place of zero. The studies wer conducted before the AHERA clearanc criteria were developed, and they do n meet all the sampling and analysi requirements. In particular, in this stud fewer location samples were taken p site (three instead of five) and th analytical sensitivity was less (0.00 instead of 0.007 s/cm^3). This means th the Z-test (required under AHERA) is les likely to detect differences betwee inside and outside concentrations i these studies than would be detected i studies in which the requirements a met. Nevertheless, the Z-test was applie to each site to gauge its performanc under nonideal circumstances.

Comparison of Airborne Asbestos Levels Before and After Removal

The average airborne asbestos concentration at each site before removal was subtracted from the average concentration after removal to give a measure of the effect of removal. A t-test was used to test whether this measure, which is approximately normally distributed, is significantly different from zero.

Comparison of Static and Aggressive Sampling

For each site and sampling period, the average airborne asbestos concentration obtained by aggressive sampling was plotted against the corresponding concentration obtained by static sampling and a correlation coefficient was calculated.

Results and Discussion

School 1

No asbestos fibers were found on any of the 13 blank filters, which indicates that contamination from sources other than the air being sampled is not an important factor. Figure 1 presents the mean airborne asbestos level at each site for each sampling period and method. Arithmetic, rather than geometric, means are reported because of the large number of zero measurements.

Indoor Airborne Asbestos Levels Before and After Removal Compared With Outdoor Asbestos Levels

Average indoor airborne asbestos levels after removal were higher than were outdoor levels. The Kruskal-Wallis test indicates significant differences among sites for both static ($p = 0.001$) and aggressive samples ($p = 0.002$). Significant differences also existed among the indoor sites ($p = 0.02$ for both static and aggressive samples), which indicates that levels after removal can differ from room to room in the same school.

Results of the Z-test show that five of the six sites failed the test under static sampling, and four failed under aggressive sampling.

Past experiences with final clearance criteria suggest that sufficient air exchange in abatement areas following final cleaning (via negative air systems) is a major factor in passing the test. Also, meticulous, repetitive wet cleaning and HEPA vacuuming of all surfaces are necessary to remove reentrainable asbestos fibers.

Comparison of Airborne Asbestos Levels Before and After Removal

Average airborne asbestos levels at each site before and after removal are presented graphically in Figure 1, which illustrates both static and aggressive sampling results. Levels were higher after removal at all sites, although the difference was not statistically significant ($t = 2.01$, $p = 0.1$, for static samples; $t = 1.17$, $p = 0.3$, for aggressive samples) because of the large variability from site to site. The Kruskal-Wallis test detected no significant differences between indoor and outdoor sites before removal ($p = 0.99$ for static samples, $p = 0.81$ for aggressive samples), but detected significant differences between indoor and outdoor sites after removal. This confirms that the situation before removal differed from that after removal. Final air quality following asbestos removal appears to be related directly to the adequacy of the final cleaning and to the degree of air exchange occurring in the work area as a

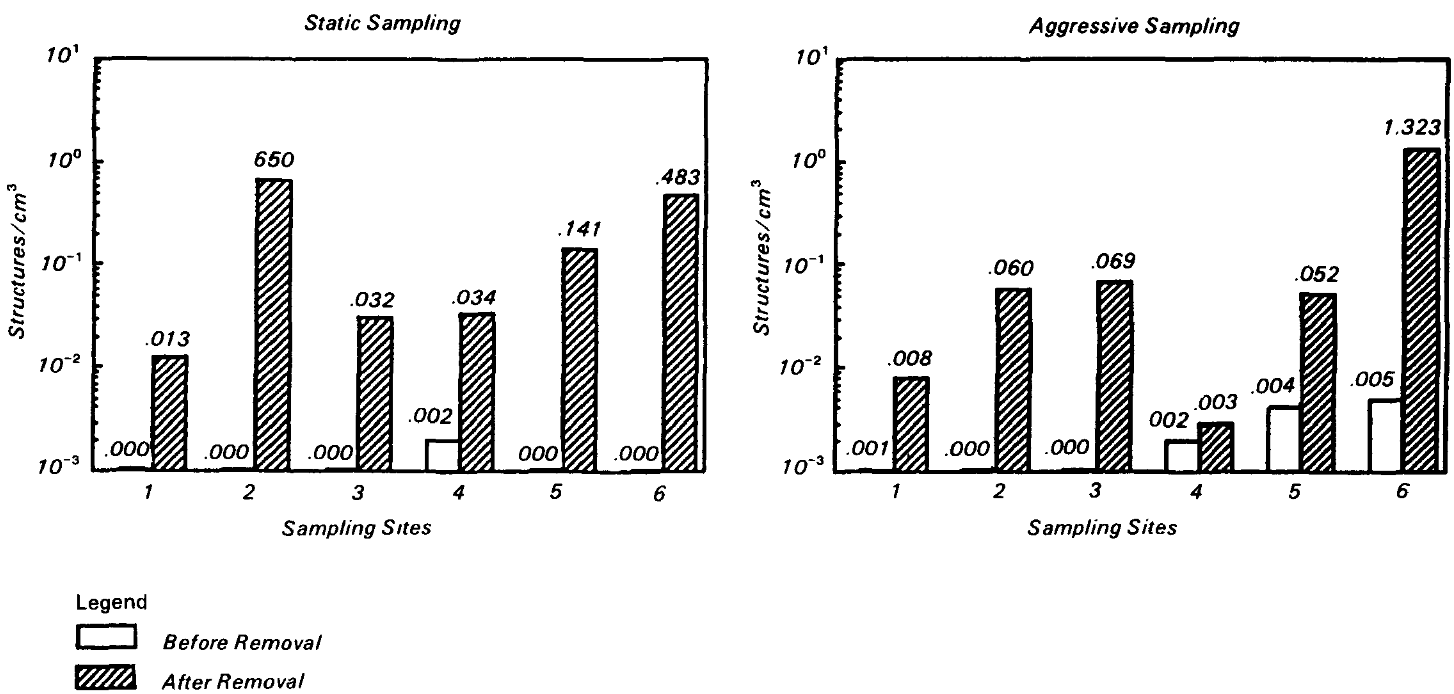

Figure 1. Average TEM airborne asbestos levels measured by static and aggressive sampling at School 1 before and after asbestos removal at each site. Sites are identified by number.

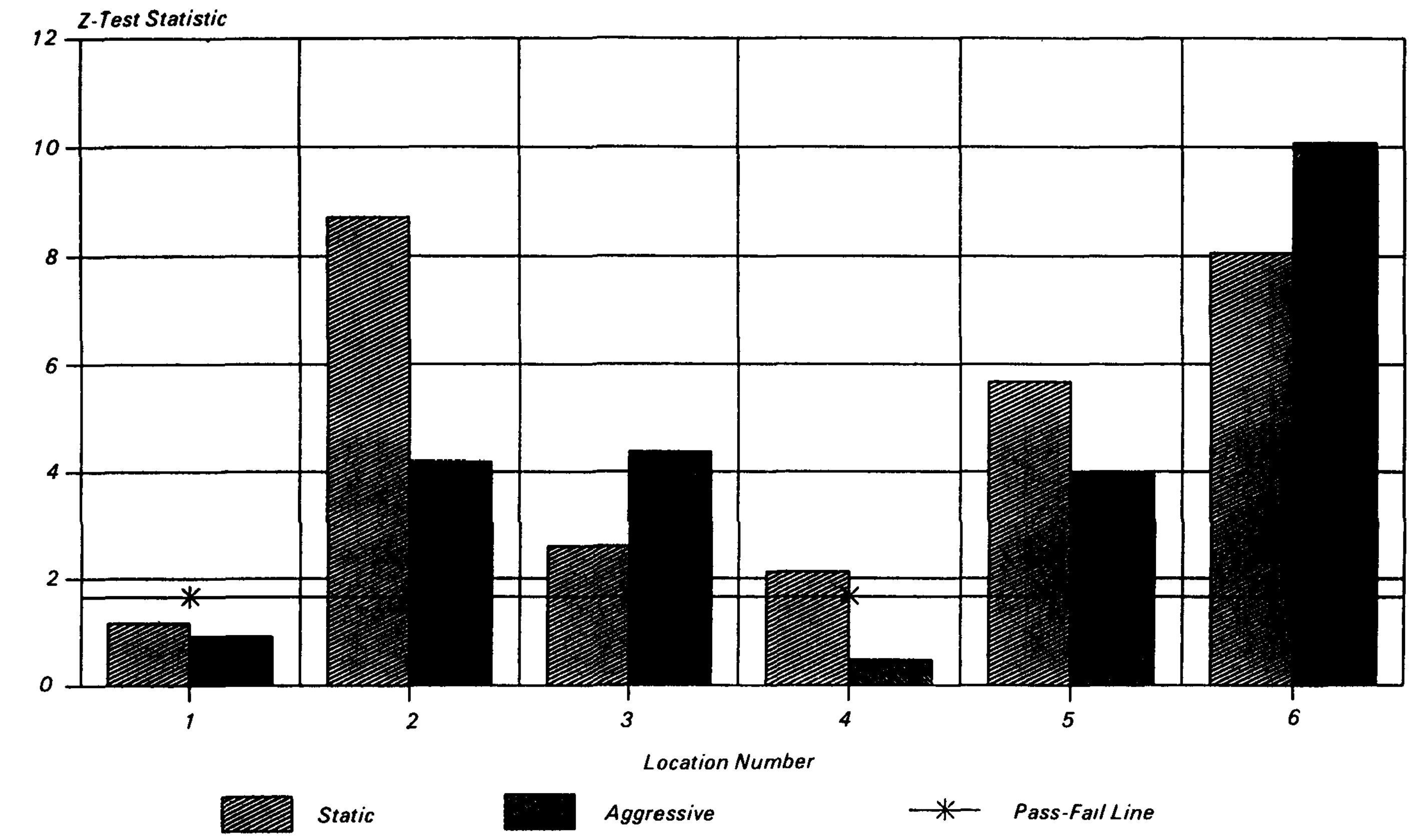

Figure 2. *Z-test for School 1 post abatement static and aggressive sampling.*

result of engineering control systems (e.g., negative air). Figure 2 presents the Z-test results for School 1.

School 2

No asbestos fibers were found on any of the 11 blank filters, which indicates that contamination from sources other than the air being sampled is not an important factor. The mean airborne asbestos level at each site for each sampling period and method are presented in the full report. Arithmetic, rather than geometric, means are reported because of the large number of zero measurements.

Indoor Airborne Asbestos Level Before and After Removal Compared with Outdoor Asbestos Levels

Average airborne asbestos levels after removal were low. No asbestos fibers were detected outdoors. The Kruskal-Wallis test detected no significant differences between indoor and outdoor sites for both static ($p = 0.46$) and aggressive samples ($p = 0.44$).

Results of the Z-test show that none of the four sites failed the test under static sampling; one site failed the test under aggressive sampling.

Comparison of Airborne Asbestos Levels Before and After Removal

Average airborne asbestos levels at each site before and after removal are plotted in Figure 3, which illustrates both static and aggressive sampling results. Levels were lower after removal at all sites except site 4 under static sampling conditions. The reduction was not statistically significant ($t = -1.5$, $p = 0.23$, for static samples; $t = 1.4$, $p = 0.26$, for aggressive samples). The Kruskal-Wallis test detected no significant differences between indoor and outdoor sites before removal for static samples ($p = 0.25$), but it did detect a significant difference for aggressive samples ($p = 0.01$). No si nificant differences were detected aft removal, which indicates that the situatic before removal differed from the situatic after removal.

Significant differences also existe among the indoor sites prior to remova which indicates that levels can differ fro room to room in the same school. Figu 4 presents the Z-test results for School

Post Abatement Clearance Concentrations

The cumulative concentrations of ai borne fibers for School 1 and School were analyzed. The data for School included 18 aggressive, 18 static, and 1 ambient samples. Figure 5 (School illustrates the cumulative average co centrations for the specific type sampling employed. The data for Scho 2 are depicted in Figure 6. The po abatement clearance data for School includes 12 aggressive, 11 static, and ambient samples.

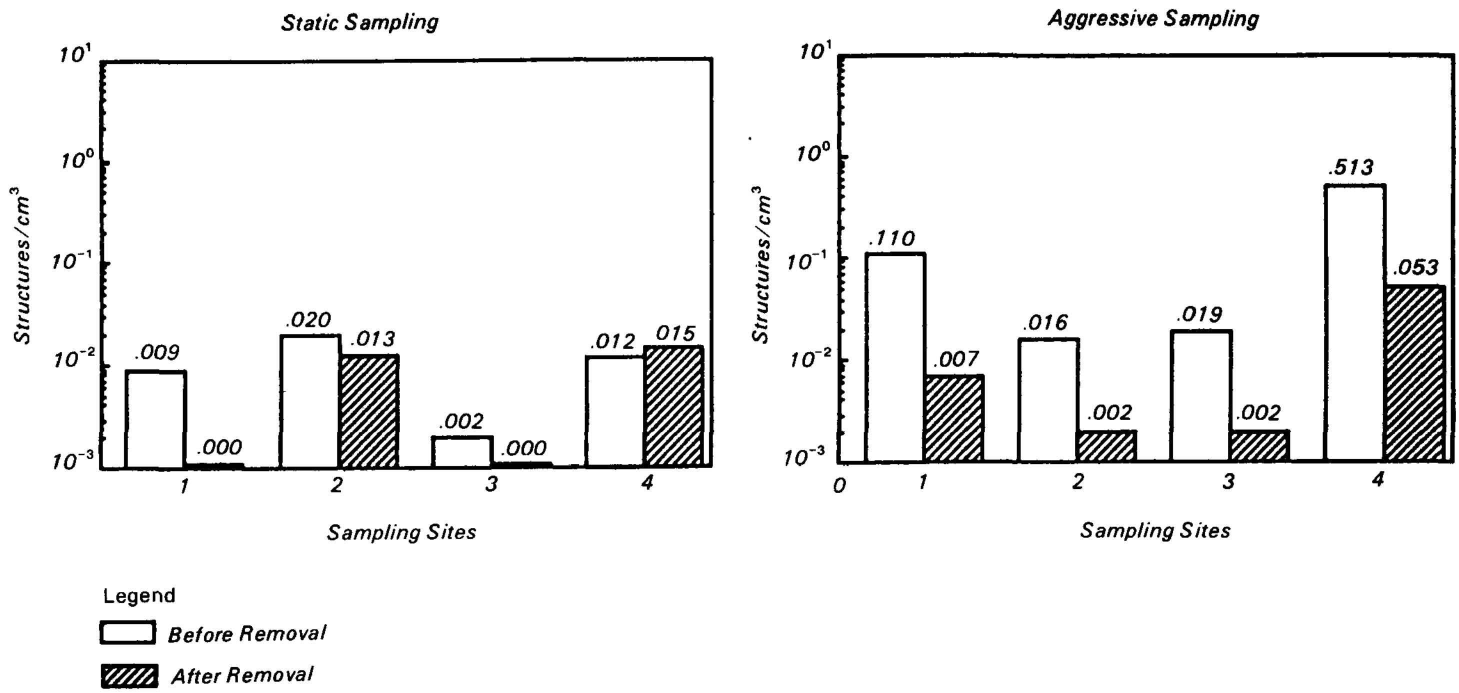

Figure 3. *Average TEM airborne asbestos levels measured by static and aggressive sampling at School 2 before and after asbestos removal at each site. Sites are identified by number.*

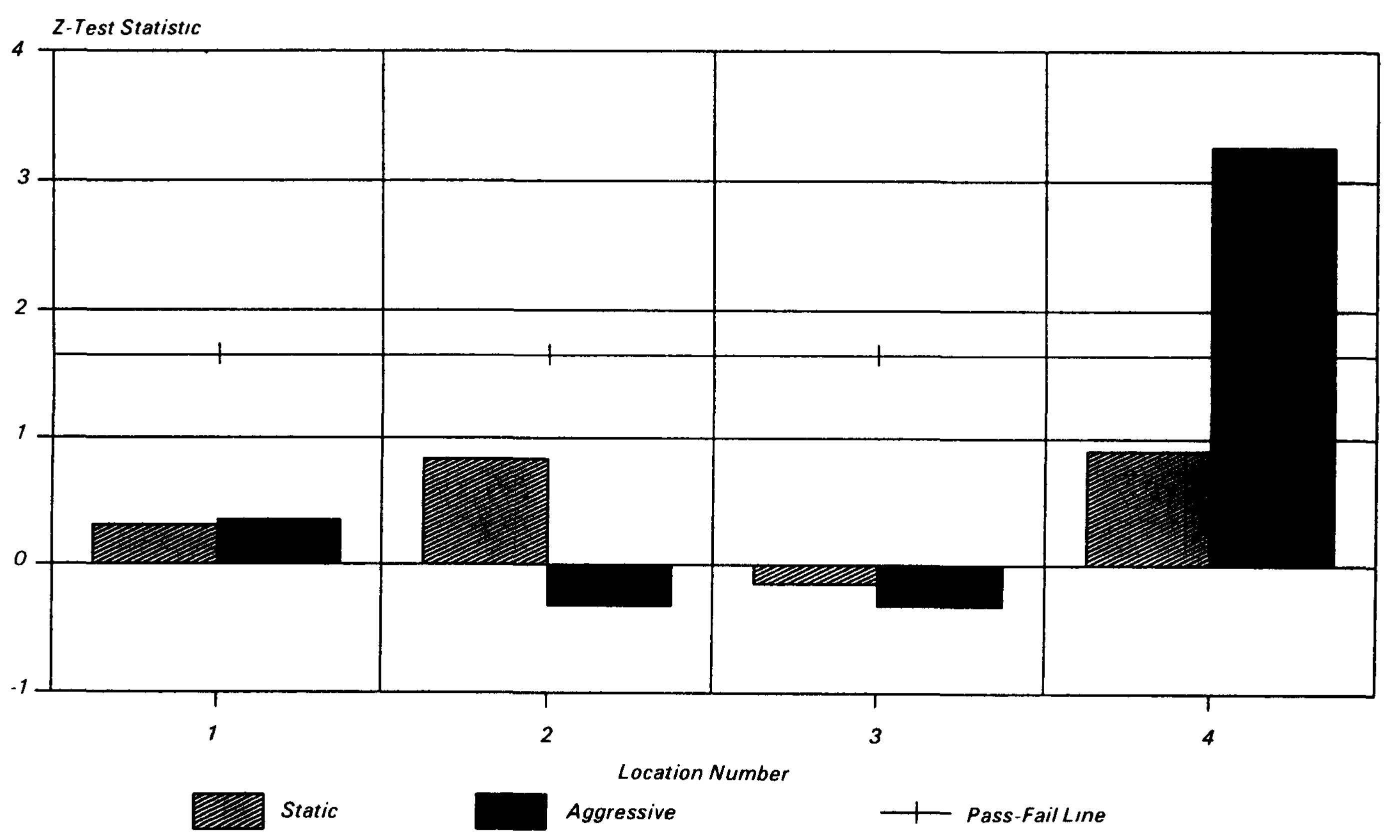

Figure 4. *Z-test for School 2 post abatement static and post aggressive sampling.*

Results and Conclusions

Results

The main results are summarized by school as follows:

School 1

- Indoor airborne asbestos levels prior to removal were not statistically significantly different from outdoor levels. The indoor levels (using both static and aggressive sampling techniques) increased after removal and were significantly higher than outdoor levels at all but one of the sites. The levels differed significantly at different sites.

School 2

- Indoor airborne asbestos levels measured by aggressive sampling were significantly higher than outdoor levels removal. Differences among indoor sites were also significant. Levels declined after removal, and with the exception of one site under aggressive sampling, they were not significantly different from outdoor levels.

Conclusions

The preceding results led to the following conclusions;

(1) At the schools surveyed, the effect of asbestos removal was unpredictable. Measured airborne asbestos levels may reflect reductions after removal in some cases and increases in others.

(2) The variability among different sites within the same building, even when the abatement operation is carried out in accordance with presumably uniform specifications, argues for the need to treat different sites as separate areas for the purpose of clearance.

(3) Aggressive sampling is appropriate for clearance testing. It tends to capture more asbestos (i.e., measurements by aggressive sampling generally produce larger values th do measurements by static sa pling), which lowers the chance declaring a worksite clean wh entrainable asbestos is still present

Recommendations

Based on the findings of this stuc three recommendations can be made:

(1) An immediate research objecti should be to identify abateme projects in which work acceptan was achieved (per the current EI clearance criteria) and to descril the final cleaning methods a engineering control strategies us to achieve acceptance.

(2) The long-term effectiveness of c rently recommended abateme methods should be investigat further. The use of aggressive sar pling and TEM Methods to Monit previously abated building are (including those that were clear

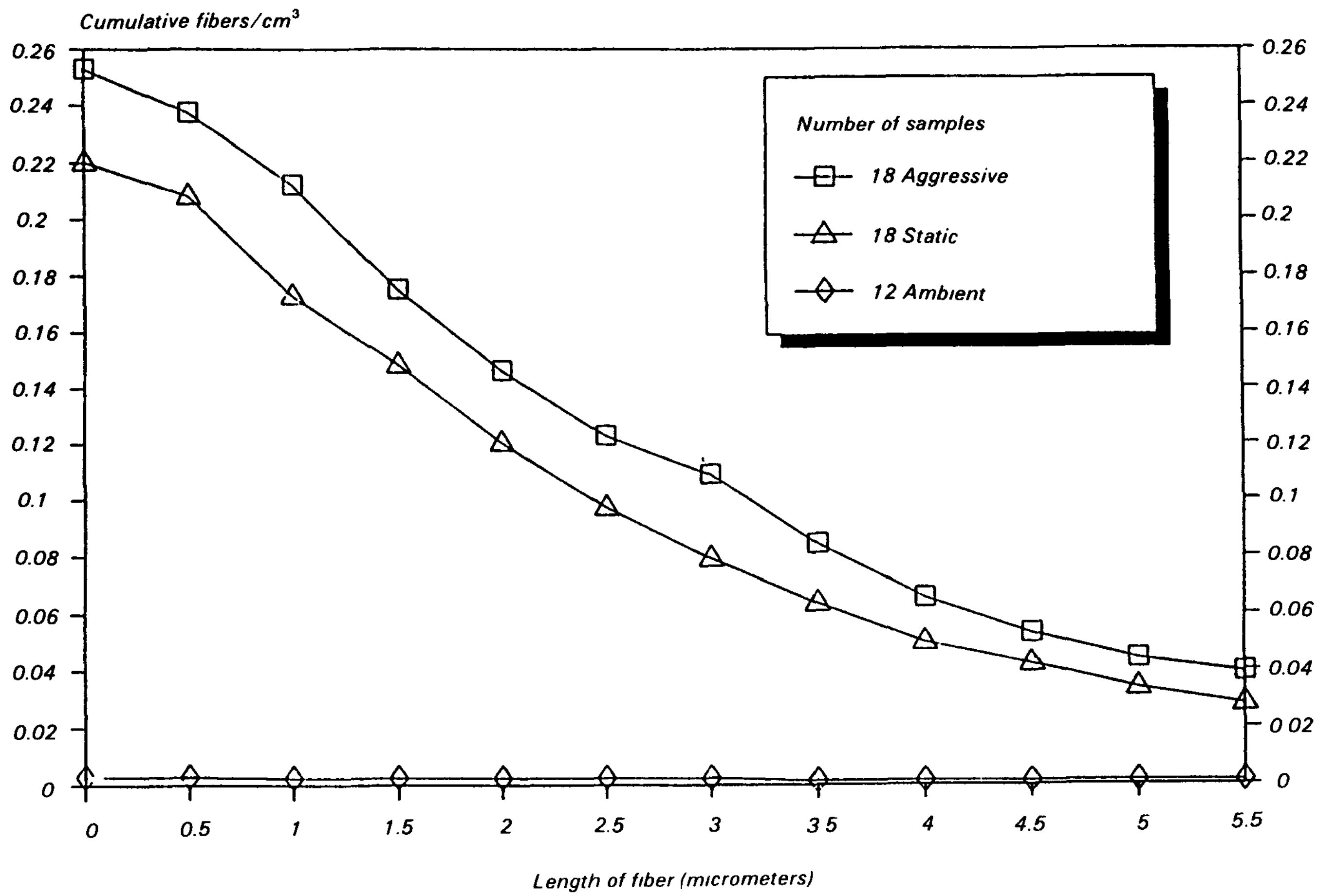

Figure 5. *Post abatement clearance data for School 1*

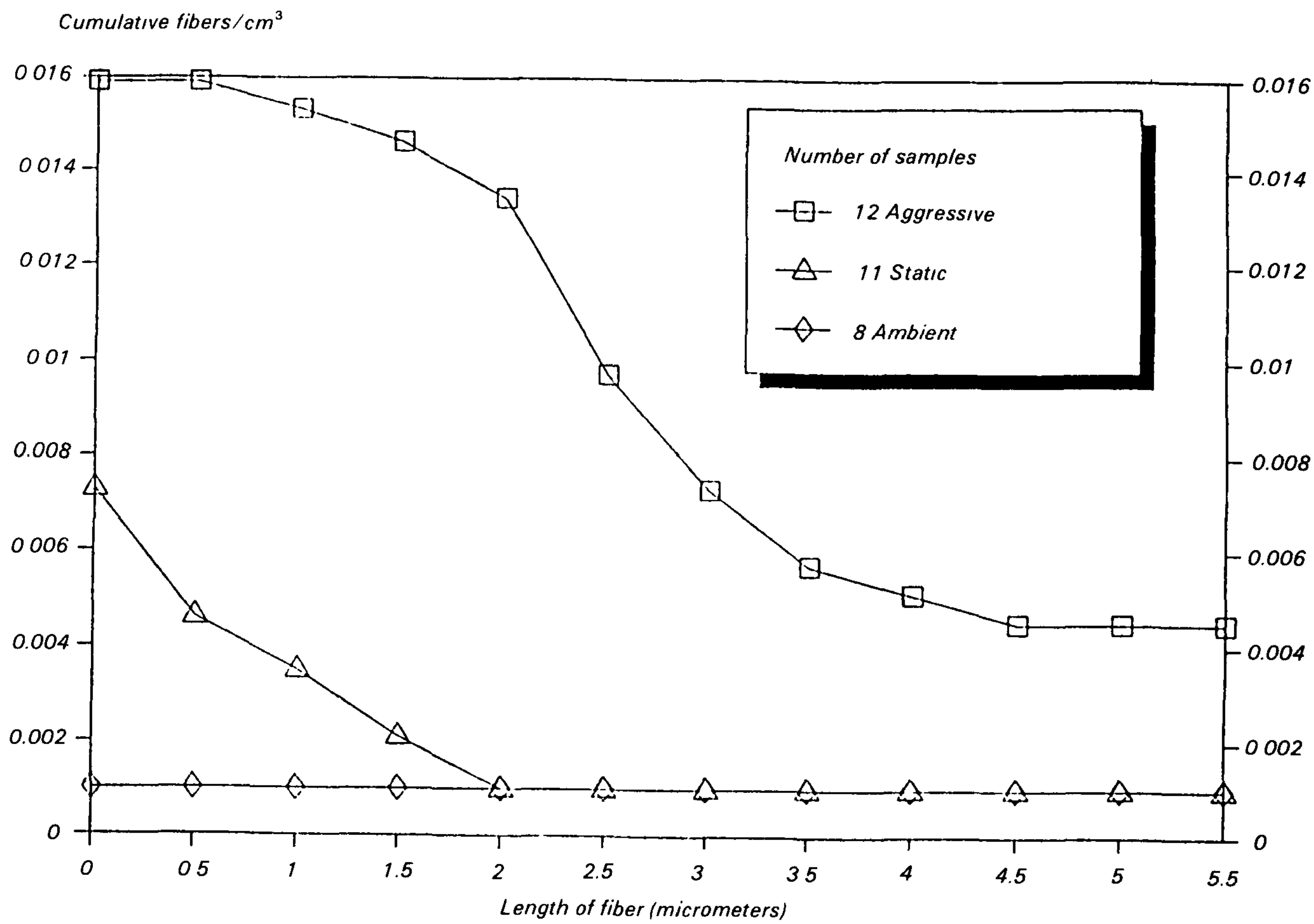

Figure 6. *Post abatement clearance data for School 2*

only by PCM methods) could help identify trends in indoor asbestos fiber concentrations over time.

(3) Future asbestos abatement research studies should focus on AHERA-Rule requirements.

The full report was submitted in fulfillment of Contract No. 68-03-4006 by PEI Associates, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

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The complete report, entitled "Evaluation of Asbestos Levels in Two Schools Before and After Asbestos Removal," (Order No. PB 89-165 922/AS; Cost: $13.95, subject to change) will be available only from:

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