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Evaluation of Glove Bag Containment and Asbestos Abatement Clearance: Methodologies for Asbestos Removal

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In a study of the effectiveness of glove bags to control asbestos exposures to workers and contamination of the environment, a four-man crew removed asbestos in eight rooms in four schools. The workers had little prior experience using glove bags and received on-the-job training in proper techniques during the early stages of the study. Daily personal breathing zone (PBZ) samples on all workers and short-term (STBZ) and work-area samples for airborne asbestos were collected and analyzed by phase contrast microscopy (PCM). The asbestos fiber concentrations of 67 PBZ samples ranged from 0.002 to 1.41 fibers/cc when asbestos lagging was being removed; 67 percent were greater than 0.2 f/cc. During an accidental release, a short-term (15 minute) concentration of 9.3 f/cc was measured. Asbestos concentrations indicated by 77 area samples were slightly lower, ranging from 0.001 to 0.96 f/cc.

For the part of the study that evaluated environmental contamination, various methodologies were used to determine the airborne asbestos concentration for clearance after abatement. Preremoval and postremoval sampling results using aggressive and nonaggressive techniques were analyzed by PCM and transmission electron microscopy (TEM). It was found that aggressive sampling and TEM analysis provided the most sensitive method to evaluate the cleanliness of the work sites that were studied. However, the TEM method has a high interlaboratory variability, and the polycarbonate filter media used in this study had a highly variable contamination problem. A standard TEM method and a laboratory certification program should be developed to help ensure the reliability of reported TEM results.

Exposure concentrations at these four schools indicate that glove bags, as used during this study, did not completely contain the asbestos being removed. Workers were exposed to airborne asbestos above the National Institute for Occupational Safety and Health recommended exposure limit and the Occupational Safety and Health Administration permissible exposure limit. Asbestos concentrations determined by aggressive sampling and TEM analysis indicated a higher level of contamination after removal than before in five of the eight rooms evaluated. Although worker training and experience are important components in performing proper abatement, this study of glove bags did not provide a basis to specify conditions under which adequate containment can be ensured. Because of the uncertainty in controlling exposures during the use of glove bags, it is essential to provide a back-up containment system (e.g., isolation, barriers, negative air), personal protective equipment (e.g., disposable coveralls), and respiratory protection.
Froehlich, P.A.; Hollett, B.A.: Evaluation of Glove Bag Containment and Asbestos Abatement Clearance: Methodologies for Asbestos Removal. Appl. Occup. Environ. Hyg. 8(11):937–944; 1993.

Introduction

Glove bags were developed as an engineering control for protecting asbestos abatement workers and maintenance personnel from exposure to asbestos fibers during the removal of asbestos pipe insulation. Glove bags are similar to a glove box but are essentially flexible, clear, or semitransparent plastic bags with gloves sealed in one side. Although they were originally developed for use on horizontal runs of pipe, they have been adapted for use in other configurations for industrial and building maintenance activities. Sections of insulated pipe are isolated within the bags by means of tape, zippers, or straps, so that all insulation materials are contained during removal operations. An internal pouch holds tools needed for loosening the pipe lagging and cleaning the pipe. In the mid 1980s, the Occupational Safety and Health Administration (OSHA) and the U.S. Environmental Protection Agency (EPA) assumed that glove bags provided protection equivalent to a full enclosure and decontamination facility.[1,2] Because of the widespread use of glove bags with the possible lack of any back-up containment, researchers from the National Institute for Occupational Safety and Health (NIOSH) studied the efficacy of this control technique in regard to worker exposures. In addition, abatement site clearance test methods were evaluated to assist the EPA in selecting appropriate methods to assure that a facility is free of airborne asbestos after abatement is accomplished.

A NIOSH technical report describing the work, sampling results, and conclusions has been published recently.[3] The field work for this study was completed in July 1985, and to our knowledge this is one of the first studies to document the efficacy of the glove bag technique to control asbestos during abatement activities. The purpose of this article, therefore, is to report in the technical literature the results of this research; we believe that it describes typical asbestos abatement practices in use before the enactment of the Asbestos Hazard Emergency Response Act of 1986 (AHERA) and the 1988 revision of CFR 1910.1001 reducing the OSHA permissible exposure limit (PEL) of airborne asbestos to 0.2 fibers per cubic centimeter (f/cc) of air.

Methodology

Airborne asbestos concentrations resulting from pipe lagging removal were documented in four public schools where glove bags were used as a control technique. Two rooms, free of visible asbestos debris and with pipe lagging in good repair, were selected in each school. All asbestos removal activities evaluated were performed by the same four-man crew.

Generally, two personal breathing zone (PBZ) samples were collected on each worker each day; sampling times ranged from 1 to 4 hours, depending on the tasks performed. Time-weighted average (TWA) exposure measurements were estimated by combining sequential morning and afternoon samples; total sampling time (the sum of the two samples) ranged from 4 to 6 hours. Short-term, 15 to 20 minute, PBZ (STBZ) samples were taken both in the morning and afternoon at opportune times or when higher exposures were anticipated (e.g., when a bag was being moved). Area samples were taken proximate to the removal activities and at another point in the room but distant from the activities; sampling times were coordinated with the PBZ samples. Ambient samples (8 hours) were obtained outside the building through windows distant from the work area. Preremoval and postremoval samples (8 hours) were obtained in the selected rooms to assess the overall efficacy of the removal method and to assess clearance measurement methodologies.

The PBZ and STBZ samples were collected at 3.5 L/min by NIOSH Method 7400 (0.8-μm pore-size cellulose ester filter and back-up pad in an open face mode in a 25-mm diameter, three-piece cassette with a 50-mm extension cowl).[4] The cowls were wrapped in aluminum foil to minimize static electric effects (conductive cowls were not readily available at the time of the study).

Area samples also were collected at a rate of 3.5 L/min. Side-by-side area samples were collected during working periods using 37- and 25-mm diameter cellulose ester filters similar to those used for personal sampling. The cassette covers were removed to provide open face sampling.

The preremoval and postremoval area samples were taken both by nonaggressive and aggressive methods and analyzed by phase contrast microscopy (PCM) and by transmission electron microscopy (TEM). The sampling methods are described in EPA Guidance Manuals, referred to as the "Blue Book"[5] and the "Purple Book,"[6] respectively. Briefly, nonaggressive sampling was conducted in a quiescent atmosphere, after allowing at least 24 hours for the room to dry out when the sampling followed wet cleaning. For aggressive sampling, dust and fibers were dislodged from walls, ceilings, and other surfaces by a 5- to 10-minute blowdown with a leaf blower; two oscillating pedestal fans were then operated during the 8-hour sampling period to keep dust and fibers suspended. Three side-by-side samples were taken in the center of the room, two on 37- and 25-mm diameter cellulose ester filters described above. The third sampler utilized a 37-mm, three-piece cassette and a 0.45-μm pore size polycarbonate filter with a 5.0-μm pore size cellulose ester back-up filter and a supporting pad. Samples were analyzed by NIOSH P&CAM 239,[7] NIOSH Method 7400, NIOSH Method 7402,[8] and the Yamate Revised EPA Provisional methods.[9]

Work Activities

To isolate the study areas from the rest of the building where other abatement activities were also being done, polyethylene sheeting (poly) was taped over vents and windows and doors were closed with double flap poly curtains. Lighting, other fixtures, and immovable furniture within these rooms and nonconcrete floors under the working areas were also covered with poly. The surface of the lagging was dampened with a mist of amended water (water containing agents to enhance the wetting process) to control surface dust. The pipes were then wrapped loosely with poly to restrict additional contamination of the work site if vibrations and movement of the pipes from the removal operations caused further deterioration of the lagging.

The amount of lagging removed from each room varied between 160 and 230 linear feet per room on pipes 1.5 to 6 inches in diameter; the lagging contained up to 40 percent of chrysotile asbestos. Sampling was conducted for 4 consecutive days in each of the first two buildings and for 3 consecutive days in each of the last two.

The contractor had a respiratory protection plan. The abatement workers were instructed in the use of and fitted with half-face cartridge respirators with high efficiency particulate-air (HEPA) filters. They were required to and did wear respirators during removal activities. Disposable coveralls were furnished and also worn at these times.

The work crew had experience in asbestos removal but were not trained in the proper use of glove bags. On the first day at the first school the workers affixed glove bags to the poly covered pipes with duct tape at widely separated intervals but did not seal them around the pipes. The bags served as receptacles for debris; the gloves were not used. The workers cut away the poly wrap, freed the lagging, and allowed it to fall into the bag. The lagging was wetted as it was removed from the pipe using 2- to 3-gallon, hand-pump garden sprayers fitted with 30-inch hoses. The sprayers were lifted to the working level and often hung from the pipes. Workers periodically dismounted from ladders and platforms to refill the sprayer and pump up the pressure. The bare pipe was washed with water and rags, usually after the bag had been moved to the next location.

On the following day, the NIOSH survey team provided the work crew with rudimentary instructions and training on abatement using glove bags. During the second week, at the second school, the workers were shown an instructional video and provided on-the-job training by a National Asbestos Council Certified Field Trainer. The NIOSH researchers observed that the workers' techniques improved with respect to keeping the bags sealed to the pipe, thoroughly wetting the lagging as it was removed, and maintaining control while moving the bags and during removal of the filled bags. By the end of the NIOSH study the workers were using the following techniques:

1. Tools for cutting metal bands and lagging and cleaning rags and brushes were placed inside the glove bag, and the bag was hung from the poly wrapped, lagged pipe. The contractor provided glove bags from several manufacturers. Depending on the style of bag, it was taped or zipped closed, then the bag ends (sleeves) were taped or compressed by straps to form a seal to the poly wrapped pipe, thereby closing a length of pipe within the bag.
2. The spray nozzles and wands from the water sprayers were inserted into the bags through special ports and sealed with duct tape. The original 30-inch hoses were replaced with 10- to 15-foot long hoses so that a support worker at floor level (rather than the worker doing the asbestos removal) could refill the sprayer tank with amended water and pump up the pressure. This greatly enhanced the ability and inclination of the workers to saturate the lagging in an effort to control fiber emissions.
3. The gloves were used to remove the lagging within the sealed bag. The poly wrap and metal bands were removed and the lagging was wetted. Preformed block insulation was cut longitudinally along the length of the blocks and circumferential cuts were made with a wire saw or blade, preferably at the ends of the blocks. The lagging was sprayed with amended water, pried apart at the cut, and lowered to the bottom of the bag. Additional amended water was sprayed onto the lagging and the pipe was washed clean with wet rags. Other forms of insulation, such as asbestos cement around pipe fittings and layers of corrugated asbestos paper insulation were removed as expediently as possible. Hard-to-clean places were brushed with a nylon-bristle brush. After the lagging was removed and the pipes were washed, the end sleeve straps were loosened or the sleeves were untaped and the bag was moved along the pipeline to the next removal site. The sleeves were resealed and removal tasks were repeated.
4. When sufficient debris and water had been accumulated, the interior surface of the bag was washed down. Air was evacuated from the bag with a HEPA-filtered vacuum system; a strap was used to cinch the collapsed bag closed, then the seals were released and it was removed from the pipe. The glove bag was sealed and placed in a disposal bag that was also sealed with duct tape.
5. Spilled material was removed from the floor with a HEPA-filtered vacuum cleaner throughout the shift. As work was completed in each area, the floor was wet mopped. The sealed bags of waste were removed from the enclosure before postremoval air sampling, but the poly seals on windows, vents and doors were kept in place to prevent contamination from other areas until the building abatement was completed.

Results

In the following discussion, preparation activity refers to the wrapping of the pipes, and removal activity refers to the actual removal and handling of the asbestos containing materials. Because the time required for removal activities was considerably greater than that for preparation, daily work tasks varied. Work activities, hence sampling, included both preparation and removal on 6 days; removal was performed all day on 5 days; and on 3 days the crew worked only a half of a day doing removal.

The results of PBZ samples analyzed by PCM are shown in Table I. The concentrations of 67 samples collected during removal activity periods ranged from 0.002 to 1.41 f/cc; the average was 0.35 f/cc. Seven samples could not be counted because particulate matter obscured the fibers. During preparation activities the concentration of 24 samples ranged from 0.002 to 0.054 f/cc (average 0.02 f/cc).

Because of samples obscured by particulate and short work days, only 46 pairs of PBZ samples (i.e., two samples on one worker for 1 day) could be combined to estimate 4- to 6-hour TWA concentrations. Of these, 32 (70%) exceeded the NIOSH recommended exposure limit (REL)[10] of 0.1 f/cc and 26 (56%) exceeded the current OSHA PEL[1] of 0.2 f/cc (Table II). The objective of this research was to determine control effectiveness and not compliance with workplace standards; however, the OSHA PEL and NIOSH REL are

TABLE I. Personal Samples Collected During Asbestos Removal and Room Preparation

	During Removal					During Preparation		
	Number of Samples			Concentration		Number of Samples	Concentration (f/cc)	
Facility	Total	>0.2 f/cc	>0.1 f/cc	Average	Range		Average	Range
1	18	13	18	0.347	0.117-0.554	8	0.034	0.026-0.054
2*	17	13	15	0.303	0.043-0.606	8	0.020	0.005-0.054
3	20	19	20	0.600	0.165-1.410	4	0.008	0.004-0.011
4	12	0	0	0.012	0.002-0.023	4	0.006	0.002-0.010
Overall	67	45	53	0.351	0.002-1.140	24	0.020	0.002-0.054

*Seven samples obscured by particulate are not included.

used as points of reference. Because the workers wore respirators during removal operations, their actual exposures were less than those reported.

The analytical results of the area samples (Table III) were similar to the PBZ results. During removal, concentrations of 77 samples ranged from 0.001 to 0.956 f/cc; the average was 0.28 f/cc. One sample was obscured with particulate matter. During preparation, concentrations of 26 samples ranged from 0.001 to 0.040 and averaged 0.015 f/cc.

Of the fiber concentrations found by the STBZ samples taken during removal activities (Table IV), 51 of 70 (73%) exceeded 0.2 f/cc. One sample was obscured with particulate matter. An accidental release occurred when approximately 10 feet of lagging not enclosed in a glove bag suddenly separated from the pipe but was contained in the poly envelope. A worker erred by cutting the poly wrap to expedite removing and bagging the large pieces. A STBZ sample taken at that time indicated a peak exposure of 9.3 f/cc. If the lagging had not been enclosed, the pieces would have fallen to the floor, shattered, and created additional contamination.

Preremoval and postremoval sampling results were obtained using both PCM and TEM analysis. The postremoval samples were taken after the room was cleaned (including wet mopping and HEPA-filtered vacuuming) but before a final visual inspection required by AHERA.[2] However, this research was not designed to determine compliance with AHERA clearance regulations. These samples indicated room contamination levels caused by abatement and also demonstrated the capabilities of the sampling methods for use in clearance determinations.

PCM analyses of samples collected using the nonaggressive method revealed fiber concentrations below or near the level of quantitation and only slightly higher when the aggressive method was used (Table V). Differences between results collected on 25- and 37-mm diameter filters were negligible. The TEM analyses (Table VI) were at least 1 order of magnitude greater than were the PCM counterparts, and showed greater differences between the preremoval and postremoval samples; aggressive sampling results indicated greater differences than nonaggressive sampling. Therefore, aggressive sampling analyzed by TEM is considered to be the most sensitive method to measure contamination. The samples collected by the aggressive method and analyzed by TEM indicated higher airborne asbestos concentrations after removal in five of the eight rooms evaluated.

The TEM results are reported as "structures"; in addition to individual fibers, asbestos structures include bundles (of parallel fibers), clusters (of randomly oriented interlocking fibers), and matrixes (of fiber and other particles).[2] The minimum fiber diameter that can be routinely observed by PCM is approximately 0.25 μm. TEM analyses detect much smaller and thinner fibers. Because of the small size of the airborne fibers released during asbestos removal, fibers counted by PCM often represent only a small percentage of the fiber exposure indicated by TEM.

Discussion

Several concerns were identified in the course of the TEM analysis of the samples from this study. Analyses of the

TABLE II. Average TWA* of Personal Samples Collected During Asbestos Removal

	Number of TWA Samples			Concentration (f/cc)	
Facility	Total	>0.2 f/cc	>0.1 f/cc	Average	Range
1	14	9	13	0.26	0.10-0.49
2	9	7	8	0.26	0.03-0.35
3	12	11	12	0.49	0.16-0.80
4	10	0	0	0.01	0.003-0.015
Overall	45	27	33	0.26	0.003-0.80

*Time-weighted average over actual working time = 4 to 6 hours (see text).

TABLE III. Area Samples Collected During Asbestos Removal and Room Preparation

	During Removal			During Preparation		
	Number of	Concentration (f/cc)		Number of	Concentration (f/cc)	
Facility	Samples	Average	Range	Samples	Average	Range
1	20	0.30	0.090-0.59	10	0.022	0.009-0.040
2*	23	0.25	0.030-0.77	8	0.016	0.011-0.023
3	20	0.54	0.002-0.96	4	0.005	0.003-0.009
4	14	0.01	0.001-0.01	4	0.007	0.003-0.013
Overall	77	0.29	0.001-0.96	26	0.015	0.003-0.040

*One sample obscured by particulate is not included.

filter blanks indicated that the polycarbonate media was contaminated with small amounts of asbestos. Polycarbonate filter media from the same manufacturer was used in 10 other EPA TEM clearance sampling studies underway at that time. An EPA peer review conference[11] found that the polycarbonate filter media in all these studies were contaminated with asbestos; the contamination was nonuniform and apparently randomly distributed across media lots. Since the contamination of the polycarbonate filters seemed to be random, it would add to the background on the filters but should not introduce a systematic bias in any of the samples. Therefore, trends seen in the comparison between the preremoval and postremoval samples should not be affected by this contamination. Another concern stemming from this conference was the very high interlaboratory analytical variability in the analyses of the samples, in large part because of the lack of interlaboratory standardization. Because of these and other factors, the accuracy of the concentrations reported in Table VI is not as well established as the PCM results.

The findings of this study also were influenced by other factors. The rooms selected were free of visible asbestos debris. If the lagging had been in poor repair and/or rubble had been evident on floors and ledges, the preparation activity exposure and preremoval room contamination levels would have been undoubtedly much higher. Also, in the second building, seven PBZ samples taken during removal activities could not be counted because of particulate overloading; hence some higher exposure data may have been lost.

Conclusions/Recommendations

As used in this evaluation, glove bags did not completely contain airborne asbestos when pipe lagging was being removed. Glove bags can be a useful engineering control to reduce worker exposure to asbestos during the removal of asbestos containing materials. However, workers' exposures to airborne asbestos were consistently less than the NIOSH REL and the OSHA PEL in only one of the four facilities surveyed. Based on these results, it is prudent to assume that glove bags will afford varying degrees of containment, depending on the specific configuration of the structure from which asbestos is to be removed and the manner in which the glove bags are used by the workers.

This investigation was not designed to demonstrate the effect of worker training on glove bag containment efficacy and it did not provide a basis to specify conditions under which adequate containment can be assured. Worker training and experience are important components of a reliable system of control measures; however, even work performed by well-experienced crews is subject to accidental releases. Although engineering controls are the primary preventative measure, the use of personal protective equipment (e.g., disposable coveralls) and respiratory protection during any glove bag operation is recommended because of the potential for undetected leakage of the glove bag and accidental rupture of the bag or seals. Because of these uncertainties, the use of a back-up containment system (e.g., isolation, barriers, negative air) is appropriate.

TABLE IV. Short-Term* Breathing Zone Samples Collected During Asbestos Removal and Room Preparation

	During Removal					During Preparation		
	Number of Samples			Concentration (f/cc)		Number of	Concentration (f/cc)	
Facility	Total	>0.2 f/cc	>0.1 f/cc	Average	Range	Samples	Average	Range
1	15	14	15	0.72	0.14-1.19	1	0.030	0.030
2[A]	23	20	22	0.72	0.07-2.92	7	0.031	0.017-0.045
3	17	17	17	1.76	0.16-9.29	3	0.017	0.016-0.018
4	15	0	1	0.04	0.02-0.20	3	0.015	0.014-0.016
Overall	70	51	55	0.83	0.02-9.29	14	0.025	0.014-0.045

*Approximately 15 to 20 minutes.
[A]One sample obscured by particulate is not included.

TABLE V. Asbestos Concentrations (f/cc) Found With PCM Analysis

	Nonaggressive Sampling						Aggressive Sampling					
	Preremoval			Postremoval			Preremoval			Postremoval		
	Number of Samples	Concentration		Number of Samples	Concentration		Number of Samples	Concentraton		Number of Samples	Concentration	
Location		Average	Range		Average	Range		Average	Range		Average	Range
Facility 1												
Room A	6	0.002	0.001-0.004	6	0.004	0.001-0.010	8	0.026	0.015-0.056	6	0.017	0.011-0.026
Room B	9	0.008	0.004-0.017	6	0.007	0.001-0.014	10	0.024	0.013-0.039	6	0.035	0.005-0.050
Facility 2												
Room D	6	0.001	0.000-0.002	7	0.002	0.001-0.004	6	0.002	0.000-0.004	11	0.015	0.006-0.034
Room E	6	0.002	0.000-0.005	9	0.004	0.001-0.009	6	0.017	0.006-0.039	9	0.043	0.018-0.063
Facility 3												
Room F	6	0.002	0.001-0.003	6	0.001	0.000-0.002	5	0.008	0.001-0.020	6	0.020	0.011-0.030
Room G	6	0.003	0.001-0.007	6	0.001	0.001-0.001	6	0.076	0.033-0.110	6	0.002	0.001-0.007
Facility 4												
Room H	6	0.001	0.001-0.002	9	0.002	0.000-0.008	96	0.004	0.001-0.013	7	0.002	0.001-0.003
Room I	6	0.002	0.001-0.003	9	0.002	0.001-0.005	5	0.010	0.001-0.019	8	0.004	0.001-0.007

TABLE VI. Asbestos Concentrations (structures/cc) Found With TEM Analysis

	Nonaggressive Sampling						Aggressive Sampling					
	Preremoval			Postremoval			Preremoval			Postremoval		
	Number of Samples	Concentration		Number of Samples	Concentration		Number of Samples	Concentraton		Number of Samples	Concentration	
Location		Average	Range		Average	Range		Average	Range		Average	Range
Facility 1												
Room A	3	0.089	0.052-0.120	3	0.065	0.026-0.140	3	0.143	0.112-0.160	3	0.254	0.213-0.342
Room B	3	0.065	0.040-0.087	3	0.231	0.113-0.329	3	0.192	0.055-0.292	3	0.558	0.359-0.676
Facility 2												
Room D	3	0.114	0.054-0.115	3	0.354	0.110-0.635	3	0.054	0.047-0.059	3	0.356	0.158-0.624
Room E	3	0.057	0.024-0.085	3	0.166	0.121-0.210	3	0.184	0.048-0.370	3	0.210	0.173-0.264
Facility 3												
Room F	3	NA		3	NA		3	0.064	0.035-0.096	3	0.100	0.044-0.143
Room G	3	NA		3	NA		3	0.203	0.041-0.364	3	0.154	0.052-0.312
Facility 4												
Room H	3	NA		3	NA		3	0.239	0.097-0.392	3	0.071	0.033-0.093
Room I	3	NA		3	NA		3	0.287	0.106-0.517	3	0.090	0.022-0.167

NA = not analyzed.

NIOSH recommends the use of the most protective respirators.[12] This includes any self-contained respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary, self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode when exposures exceed the NIOSH REL. Where exposure concentrations have been documented to be below the NIOSH REL, or where certain small scale, short duration tasks must be performed (e.g., maintenance and repair), or where the most protective respirators cannot be feasibly used, tight fitting, high efficiency powered air-purifying respirators and the nonpowered, full facepiece, high efficiency respirators are recommended.

The rooms were selected for evaluation because of the good condition of the pipe lagging and the absence of visible debris. The workers wore respirators during removal operations, but did not wear them during the preparation stage. It is more usual for abatement work to be performed in areas where damaged lagging and debris are present; under such conditions respiratory protection also should be worn while preparing the work site.

For clearance testing, the aggressive sampling technique is more sensitive for detecting asbestos contamination than is the nonaggressive sampling technique. When aggressive sampling and TEM analysis techniques were used, preexisting contamination was found in all of the rooms in which this study was conducted, even though these rooms were selected because of the absence of any visual contamination. Using these same sampling and analytical techniques, asbestos concentrations observed following the abatement activities but before final inspection were greater than were the preexisting contamination levels in five of the eight rooms. PCM is not reliable for clearance testing. Even when aggressive sampling techniques were used, PCM analysis could not always detect the presence of asbestos, even though fibers were observed on all samples analyzed by TEM. Furthermore, the results obtained by PCM were very close to the limit of detection for this method, and therefore, more subject to analytical error. This makes comparison with a clearance standard difficult.

Monitoring airborne asbestos concentration is necessary to verify the effective use of glove bags; both EPA and OSHA now have specific requirements for monitoring.[13,14] Frequent observation and supervision by an experienced overseer is recommended to ensure that proper practices are being used. Although conventional workplace sampling for airborne concentrations can provide only after-the-fact exposure information, it may indicate to the overseer and the removal contractor the need for improved control on future jobs. A direct-reading instrument may be useful to indicate large, accidental releases of fibers and to help minimize contamination by timely corrective actions.

The interlaboratory variability observed for the TEM analysis and the asbestos fiber contamination found on the polycarbonate filter media indicate that additional standardization and quality assurance are required. Laboratory accreditation is needed to assure that uniform sample preparation techniques and counting methods are used.

The work described in this article was performed before the enactment of AHERA and before training in asbestos abatement techniques was readily available. A recent article by Perkins *et al.*[15] reports asbestos exposures from abatement work over a 5-year period (1984 to 1989). They conclude: ". . . where ACM [asbestos containing material] is in good condition but glovebags are used for removal, the airborne asbestos hazard may increase during abatement operations and for a period of time after removal." Perkins *et al.* recommend that the use of glove bags for removal of ACM be discontinued except when used in conjunction with negative-pressure enclosures, for very small jobs for a short period of time or for emergencies, and that full-face respirators be required for workers in asbestos abatement projects. We encourage other researchers performing asbestos abatement investigations to publish their findings so that documented data is made available to the occupational and public health community.

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Disclaimer

Mention of trade names or commercial products does not constitute endorsement by the Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

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