# The Presence of Asbestos-Contaminated Vermiculite Attic Insulation or Other Asbestos-Containing Materials in Homes and the Potential for Living Space Contamination

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Abstract **Asbestos-contaminated vermiculite attic insulation (VAI) produced from a mine near Libby, Montana, may be present in millions of homes along with other commercial asbestos-containing materials (ACM). The primary goal of the research described here was to develop and test procedures that would allow for the safe and effective weatherization of low-income homes with asbestos. The presence of asbestos insulation was confirmed by bulk sampling of the suspect asbestos material. The homes were then tested for the presence of asbestos fibers in the living spaces. All 40 homes containing VAI revealed the presence of amphibole asbestos in bulk samples. Asbestos (primarily chrysotile) was confirmed in bulk samples of ACM collected from 18 homes. Amphibole asbestos was detected in the living space of 12 (26%) homes, while chrysotile asbestos was detected in the living space of 45 (98%) homes. These results suggest that asbestos sources in homes can contribute to living space contamination.**

## Introduction

For 70 years Vermiculite Mountain (also called Zonolite Mountain), located seven miles northeast of Libby, Montana, supplied over 70% of the world's vermiculite (U.S. Environmental Protection Agency [U.S. EPA], 2011a). Vermiculite was used extensively in home insulation despite the fact that it was contaminated with fibrous and nonasbestiform amphibole asbestos (Pardee & Larsen, 1929). The precise number of U.S. homes insulated with Zonolite brand vermiculite attic insulation (VAI) is unknown (Gunter, Singleton, Bandli, Lowers, & Meeker, 2005; U.S. EPA, 2011a; Zalac, 2003); however, vermiculite was widely distributed via processing plants throughout the country and may be present in millions of homes, including thousands of homes in Montana (U.S. EPA, 2011a).

In addition to vermiculite insulation, many older homes contain serpentine asbestos in commercial products such as thermal insulation, floor tiles, roofing tiles or shingles, gaskets, ceiling texture materials, and siding (Dodson & Hammar, 2006).

In the state of Montana, the Department of Public Health and Human Services (DPHHS), the Low Income Home Energy Assistance Program (LIHEAP), and the Weatherization Assistance Program participate in grant-funded weatherization activities with the goal of increasing the energy efficiency of homes that meet various program qualification guidelines. An estimated 1,500 to 2,000 qualified homes are weatherized per year throughout the state.

Unfortunately, weatherization services are denied to approximately 200 high-energy LIHEAP recipient households annually due to the presence of asbestos-containing materials (ACM) in their homes, either as loose-fill insulation in attics, in pipe or duct insulation, or in certain wall, ceiling, and siding materials. Because of potential health and safety hazards to residents and agency workers, Department of Energy weatherization rules prevent agencies from weatherizing homes with VAI or with other ACM that are friable or brittle and could potentially become airborne.

The research discussed in this article is part of a two-phase project funded by DPHHS to assess and develop weatherization protocols that may be used to safely weatherize homes that have been found to contain ACM or VAI (National Center for Appropriate Technology, 2010).

### Research Aim

The objective of our research was to confirm the presence of VAI or other ACM in homes via bulk sampling and to assess the potential for living space contamination associated with these sources. Baseline data from this Phase I study were used to develop sampling strategies, personal protective equipment (PPE) selections, and exposure control strategies for Phase II. The aim of Phase II (currently being prepared for publication) was to determine the impact of weatherization activities in asbestos-laden homes on potential living space contamination and weatherization worker exposure and to develop asbestos-safe weatherization protocols.

## Previous Studies

While substantial literature exists regarding occupational asbestos exposure, limited information is available concerning asbestos exposure in residential settings (Ewing, Hays, Hatfield, Longo, & Millette, 2010). The majority of studies associated with residential living space asbestos contamination have focused on exposure and related disease among household members of occupationally exposed workers (Anderson, Lilis, Daum, & Selikoff, 1979; Epler, Fitz Gerald, Gaensler, & Carrington, 1980; Kilburn et al., 1985; Miller, 2005; National Institute of Occupational Safety and Health [NIOSH], 1995; Peretz, Van Hee, Kramer, Pitlik, & Keifer, 2008; Sider, Holland, Davis, & Cugell, 1987; Whitehouse, 2004) or residential exposure in areas near asbestos-related industries or naturally occurring asbestos deposits (Adgate et al., 2011; Kumaqai, Kurumatani, Tsuda, Yorifuji, & Suzuki, 2010; Pan, Day, Wang, Beckett, & Schenker, 2005; Reid et al., 2007).

Cowan (1997) discussed contractor asbestos exposures from a building demolition that contained VAI. The majority of bulk VAI samples collected prior to demolition revealed less than 0.1% asbestos, with detectable concentrations ranging from 0.1% to 5%–10% actinolite or tremolite. The initial demolition work was conducted without dust suppression and air monitoring revealed asbestos concentrations ranging from 13 to 172 structures per mL (s/mL) by transmission electron microscopy (TEM).

A study (U.S. EPA, 2003) was conducted to estimate asbestos exposures from vermiculite insulation in containment structures and occupied and unoccupied Vermont homes with asbestos concentrations in bulk VAI samples ranging from nondetect to <0.1% by TEM. The implications of that study were that routine disturbances of vermiculite insulation by homeowners can result in asbestos exposure via inhalation of airborne fibers.

In another study, activity-based air and surface sampling was conducted in three homes to evaluate amphibole asbestos exposures during specific activities in attics containing VAI (Ewing et al., 2010). Personal and area air sampling revealed significant concentrations of airborne amphibole asbestos above background concentrations when VAI was disturbed. The highest personal and area concentrations were observed when VAI was moved aside with a dry sweeping method.

While the studies described above provided initial insight into potential exposures associated with demolition of structures containing VAI and the potential for exposure associated with activities that may be performed primarily in the attic of homes with VAI, the impact of VAI or other ACM on potential living space contamination outside of U.S. EPA Superfund sites such as Libby, Montana, has not been fully addressed.

## Methods

Sampling for our research was conducted in 46 single-dwelling homes throughout Montana. Participants who were previously denied weatherization benefits because of the presence of asbestos in their home were recruited via telephone contacts and mailings. Participants first received an explanation of the research. Investigators then conducted a visual inspection of the home and collected bulk samples of VAI or other suspect sources of ACM. When the presence of asbestos was confirmed in VAI or other bulk sources of ACM via independent laboratory analyses, baseline air and surface sampling was performed to assess potential living space contamination.

### Bulk Sampling Methodology

Prior to bulk sample collection, a visual inspection was conducted in each home. This inspection included occupant interviews to obtain home construction histories, identification of attic access ports, inspection of living spaces for potential pathways of vermiculite insulation contamination (holes or gaps in the ceiling), and documentation of other suspect ACM in the homes as well as the condition of these materials.

A visual inspection of the attic was documented and recorded with photos. If VAI was observed in any portion of the attic, a one-gallon sample was collected. Several attics revealed vermiculite mixed with cellulose or fiberglass insulation. Suspect ACM samples were also collected, most commonly from thermal system insulation (TSI) sources. Bulk VAI and ACM samples were sent to an independent laboratory for analysis by polarized light microscopy for asbestos using a modified U.S. EPA/600/R-04/004 and U.S. EPA-600/R-93/116 method, respectively (U.S. EPA, 2004). The laboratory used is accredited by the American Industrial Hygiene Association, the National Voluntary Laboratory Accreditation Program, and the New York State Department of Health Environmental Laboratory Approval Program.

### Baseline Living Space Sampling Methodology

After positive identification of asbestos was documented through bulk sampling, high-volume air and surface dust samples were collected from each home. High-volume air samples were collected using a minimum of five high-flow (9.5–9.9 L/min.) vacuum pumps positioned throughout the living spaces of each home. Sampling cassettes fitted with 0.8 µm 25 mm mixed cellulose ester membrane filters were positioned five to six feet above the ground. The mean sample duration was two hours. The air samples were analyzed for asbestos per National Institute of Occupational Safety and Health's (NIOSH's) *Asbestos and Other Fibers by PCM: 7400* (NIOSH, 1994) by the independent laboratory. Samples that revealed phase contrast microscopy (PCM) concentrations greater than 0.01 fibers/mL (f/mL) were further analyzed by U.S. EPA's Asbestos Hazard Emergency Response Act, Airborne Asbestos by TEM (Asbestos, 1987). In the event that none of the samples revealed PCM concentrations greater than 0.01 f/mL, the two highest PCM samples from each home were selected for TEM analysis.

Surface dust samples were collected from numerous room surfaces via wet wipe and micro-vacuum techniques. Wipe samples were collected from floors, interior window sills, ductwork, furniture, and appliances using the American Society for Testing and Materials (ASTM) D 6480-05 procedures, "Wipe Sampling for Settled Asbestos" (ASTM, 2010) and analyzed by TEM by the independent laboratory.

Micro-vacuum samples were also collected throughout homes on surfaces not suitable for surface wipes (carpets, porous furniture) using ASTM Method D 5755-03 procedures, "Microvacuum Sampling and Indirect Analysis of Dust by TEM for Asbestos Structure Number Concentration (ASTM, 2009)." Ten percent field blanks were submitted for the high-volume air, surface wipes, and micro-vacuum samples.

### Background Concentrations

Air and surface concentrations of 0.01 f/mL (70 structures per square millimeter [s/mm$^2$]) (confirmed by TEM analysis) and 10,000 structures per square centimeter (s/cm$^2$), respectively, were adopted for this project as values, that if exceeded, required the home to be cleaned by a state licensed asbestos abatement contractor (LAAC) and cleared via air sampling prior to the home being considered for the Phase II component of our research. The air concentration of 0.01 f/mL (70 s/$mm^2$) represents the Montana state asbestos abatement project clearance concentration (State of Montana Department of Quality Permitting and Compliance Division, 2005). In terms of surface concentration, a review of available literature indicates that a surface may be considered "clean" when the asbestos concentration is below 1,000 s/$cm^2$. A surface would be considered contaminated when the asbestos concentration is greater than 100,000 s/$cm^2$ (Millette & Hays, 1994). Based on existing scientific literature, an acceptable background level for surface samples of 10,000 s/$cm^2$ was adopted for this research.

### Precautionary Measures

The study protocol was approved by the institutional review board at Montana State University. Study participants received an explanation of the research and provided written consent prior to any research activities. In an effort to minimize potential asbestos exposures to home occupants and research investigators, the following additional precautions were taken.

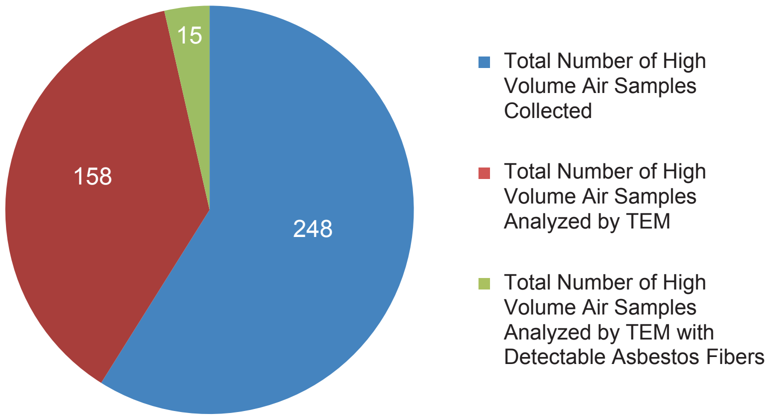
High-volume air sampling was conducted with nonaggressive sampling methods. Attic spaces were accessed from the exterior of the home whenever possible. If attic spaces were entered from the home interior, a 6-mL plastic containment structure was constructed around the access port prior to entry. Similar containment practices were used for all bulk ACM sample collection. Investigators were suited in level C PPE prior to entering any attic space. All investigators obtained medical clearance to wear negative pressure respirators and passed quantitative fit tests within the past year.

## Results

Visual inspection and bulk sampling in the 46 homes that were part of our Phase I assessment revealed VAI present in 40 of the 46 homes. In addition, one of the homes without VAI contained vermiculite insulation in two walls. Bulk vermiculite asbestos concentrations were reported by the laboratory as "present" or "absent." All of the bulk VAI samples collected revealed the presence of

FIGURE **1**

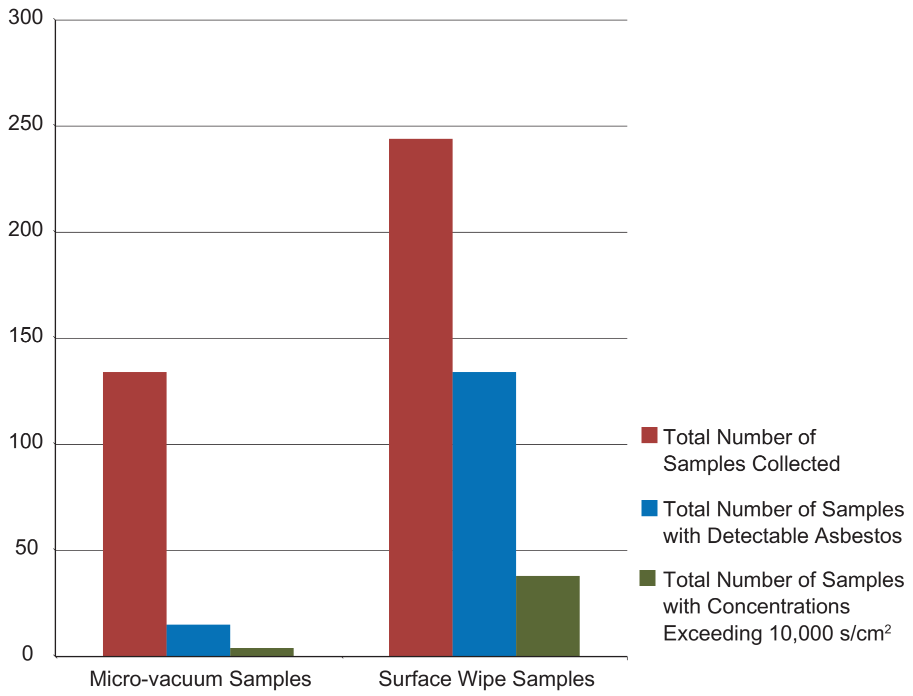
**Summary Results for High-Volume Air Sampling**




Two hundred forty-eight high-volume samples were collected (excluding field sample blanks) and analyzed by phase contrast microscopy. Of these, 158 were further analyzed by transmission electron microscopy (TEM). Fifteen of the TEM air samples revealed detectable asbestos fibers.

FIGURE **2**

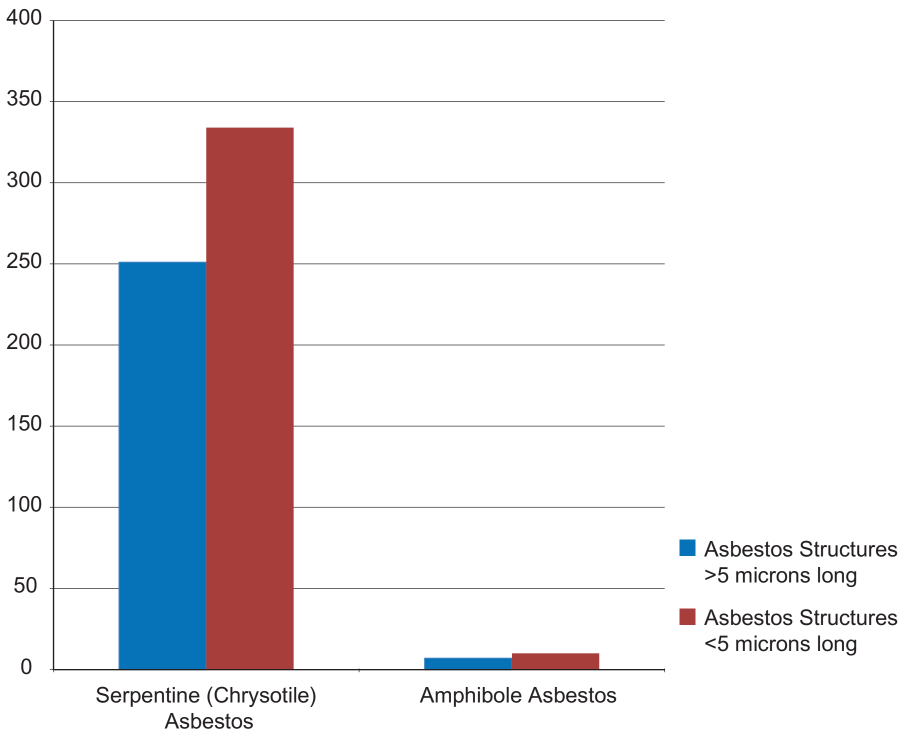
**Summary Results for Surface Sampling**




One hundred thirty-four micro-vacuum surface samples and 244 surface wipe samples were collected. Of these, 23 and 134 micro-vacuum and surface wipe samples, respectively, revealed detectable asbestos fibers. Four micro-vacuum and 38 surface wipe samples revealed asbestos concentrations exceeding the 10,000 s/$cm^2$ concentration adopted as the background surface concentration for our study.

FIGURE **3**

**Summary Results for Surface Wipe Sampling**




In terms of individual asbestos structures identified in surface wipe samples, 585 structures were chrysotile while 17 were identified as Libby amphibole or actinolite/tremolite. Asbestos structures less than 5 µm are distinguished from asbestos structures greater than 5 µm for both families.

asbestos. Thirty-nine samples of bulk ACM were also collected in these homes. Twenty-five (64%) of these samples contained greater than 1% asbestos. The majority of positive bulk ACM samples were collected in the basement area and were chrysotile-based TSI materials. These were collected in eighteen homes. Fourteen homes contained both VAI and other ACM, while four homes contained only ACM other than VAI.

Summary high-volume air sampling results are presented in Figure 1. Two hundred forty-eight high-volume air samples (excluding field blanks) were collected in the 46 homes. All of the samples were initially analyzed by PCM. The mean PCM concentration for these samples was 0.016 f/mL with a standard deviation (*SD*) of 0.014 (not shown in Figure 1). Samples with PCM concentrations greater than the clearance concentration of 0.01 f/mL were further analyzed by TEM. If none of the samples from an individual home sample set exceeded this value, the two highest PCM samples were selected for TEM analysis.

One hundred fifty-eight (64%) of the PCM samples were analyzed by TEM. Of these, 15 (9.5%) samples revealed detectable levels of asbestos. These 15 samples were collected in 11 separate homes. One of the samples analyzed by TEM exceeded the clearance concentration of 0.01 s/mL (or 70 s/mm$^2$). This sample was collected in the basement area of a home and revealed chrysotile asbestos structures.

One hundred thirty-four baseline micro-vacuum samples were collected in the 46 homes on porous surfaces not suitable for surface wipe sampling. Summary baseline micro-vacuum sample results are presented in Figure 2. Of the 134 samples, 23 (17%) revealed detectable asbestos concentrations. Four samples (3%) revealed asbestos concentrations greater than the background surface concentration of 10,000 s/cm$^2$ adopted for this project. These four samples were collected in four separate homes. All four of these samples revealed chrysotile asbestos structures.

Summary surface wipe sample results are also presented in Figure 2. Two hundred forty-four surface wipe samples (excluding field blanks) were collected in the 46 homes during this Phase I research and analyzed by TEM. One hundred thirty-four (55%) of these samples revealed detectable levels of asbestos while 38 (16%) of the total wipe samples collected revealed asbestos concentrations greater than the background surface concentration of 10,000 s/cm$^2$ adopted for this project. All 38 of these samples greater than the adopted background surface concentration were due to chrysotile contamination and were collected in 27 separate homes.

For surface wipe samples, in terms of individual asbestos structure counts reported by the laboratory, 585 structures were chrysotile (Figure 3). Three hundred thirty-four of these chrysotile structures were <5 µm and 251 were >5 µm long. Seventeen asbestos structures were amphiboles identified as Libby amphibole or actinolite/termolite. Ten of these amphibole structures were <5 µm and seven of these structures were >5 µm in length.

## Discussion

The information presented in this article was derived from Phase I of a larger research project. For the Phase I assessment described here, homes that revealed any air or surface sample above the clearance concentrations adopted for this project were cleaned and cleared (via air sampling) by an LAAC prior to participation in Phase II. Twenty-one homes required cleaning prior to Phase II.

Since the majority of the homes had VAI insulation containing amphibole asbestos, it is very likely that the insulation was derived from the Libby, Montana, Zonolite Mine. While it was difficult to make predictions for other homes, these data indicate that a high likelihood exists that vermiculite insulation, especially in Montana homes, contains asbestos.

In addition to the VAI, 18 separate homes contained ACM materials primarily associated with TSI found in basement areas.

Although 87% of homes contained asbestos-contaminated VAI and 39% of the homes contained other ACM, chrysotile asbestos (associated with ACM) was the primary type of asbestos detected in living space air and surface samples.

This is most likely associated with historic asbestos sources in the home that may have been replaced in remodeling projects (furnaces and ductwork with TSI, flooring materials, etc.), suggesting that chrysotile asbestos associated with residential commercial products may pose a greater potential exposure risk to home occupants than amphibole asbestos from VAI.

It is important to note, however, that although the homes were inspected for suspect ACM and bulk samples were obtained when identified, the composition of all historical construction materials was not accounted for. Homes may have contained external asbestos siding, flooring, etc., that was covered by newer materials. This may result in substantial underreporting of the ACM sources in each home. This hypothesis is strengthened by the observation that 60% of homes with detectable chrysotile in air samples and 56% of homes with detectable chrysotile in surface samples contained no sources of ACM identified through visual inspection and bulk sampling.

Asbestos was not detected in the majority (89.5%) of high-volume air samples and only one high-volume air sample revealed an asbestos concentration above the clearance concentration of 0.01 s/mL. These findings are similar to Ewing and co-authors' (2010) study, which reported low amphibole air concentrations in the attics and living spaces prior to disturbing VAI. As with our research, the air sampling conducted in Ewing and co-authors' study did not employ active sampling methods (disturbing settled asbestos with high velocity air). It is crucial to note, however, that when vermiculite was disturbed during attic cleaning (Ewing et al., 2010), worker personal breathing zone exposures were nearly 1,000 times greater than the background concentrations collected prior to cleaning.

Living space contamination was most commonly detected via surface sampling, specifically surface wipe sampling. Fifty-five percent of the surface wipes revealed detectable concentrations of asbestos in 27 homes while only 17.2% of the micro-vacuum samples revealed detectable asbestos. Although micro-vacuum techniques are most commonly used by regulatory agencies to assess asbestos surface contamination, in our study, surface wipe sampling presented a greater sensitivity for detecting asbestos fibers in living spaces.

Our study had some limitations. The 46 homes that were sampled in this study were previously identified as containing VAI or ACM. Therefore, only asbestos-positive homes were considered for this project. In addition, home occupants were required to demonstrate low-income eligibility in order to participate in our study, resulting in economic bias. Additionally, all of the homes considered for this study were in Montana. Due to the geographical proximity of these homes to the former Libby, Montana, Zonolite Mine, a high likelihood exists that vermiculite in Montana homes was derived from the Libby mine. Because the Libby Zonolite Mine supplied over 70% of the world's vermiculite, however, and since vermiculite processing facilities were located throughout the U.S., this limitation may be insignificant. As noted previously, only the asbestos content in suspect ACM, identified through visual inspection, was quantified; therefore, the historical presence of ACM in homes may be underestimated.

## Conclusion

Baseline surface sampling revealed that the living spaces of the majority of homes in the study were contaminated with asbestos above acceptable background levels and the majority of participating homes with asbestos in either vermiculite or thermal system insulation required cleaning of contaminated surfaces before weatherization activities began in Phase II of the research. A high likelihood exists that VAI in Montana homes contains asbestos, but the potential for living space contamination associated with VAI was not found to be as substantial as the potential for living space contamination associated with other ACMs present in residential building materials. The presence of asbestos in the surface dust in the older homes evaluated in Phase I of this research presents an exposure risk to home residents and building contractors who disturb the asbestos-containing dust.

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### References

Adgate, J.L., Cho, S.J., Alexander, B.H., Ramachandran, G., Raleigh, K.K., Johnson, J., Messing, R.B., Williams, A.L., Kelly, J., & Pratt, G.C. (2011). Modeling community asbestos exposure near a vermiculite processing facility: Impact of human activities on cumulative exposure. *Journal of Exposure Science and Environmental Epidemiology, 21*(5), 529–535.

American Society for Testing and Materials Standards. (2009). *D5755-09 standard test method for micro-vacuum sampling and indirect analysis of dust by transmission electron microscopy for asbestos structure number surface loading*. Retrieved from http://www.astm.org/Standards/D5755.htm

American Society for Testing and Materials Standards. (2010). *D6480-05 Standard test method for wipe sampling of surfaces, indirect preparation, and analysis for asbestos structure number concentrations by transmission electron microscopy*. Retrieved from http://www.astm.org/Standards/D6480.htm

Anderson, H.A., Lilis, R., Daum, S.M., & Selikoff, I.J. (1979). Asbestosis among household contacts of asbestos factory workers. *Annals of the New York Academy of Sciences, 330,* 387–400.

Asbestos (U.S. Environmental Protection Agency), 40 CFR Part 763 (1987).

Cowan, B.W. (1997, May). *Elevated asbestos exposures from a building demolition which contained vermiculite insulation*. Paper presented at the American Industrial Hygiene Association Conference and Exposition, Dallas.

Dodson, R.F., & Hammar, S.P. (2006). *Asbestos: Risk assessment, epidemiology, and health effects* (pp. 5–18). Boca Raton, FL: Taylor and Francis Group.

## References


Epler, G.R., Fitz Gerald, M.X., Gaensler, E.A., & Carrington, C.B. (1980). Asbestos-related disease from household exposure. *Respiration, 39*(4), 229–240.

Ewing, W.M., Hays, S.M., Hatfield, R., Longo, W.E., & Millette, J.R. (2010). Zonolite attic insulation exposure studies. *International Journal of Occupational and Environmental Health,16*(3), 279–290.

Gunter, M.E., Singleton, E., Bandli, B.R., Lowers, H.A., & Meeker, G.P. (2005). Differentiation of commercial vermiculite based on statistical analysis of bulk chemical data: Fingerprinting vermiculite from Libby, Montana USA. *American Mineralogist, 90*(4), 749–754.

Kilburn, K.H., Lilis, R., Anderson, H.A., Boylen, T., Einstein, H.E., Johnson, S.J.S., & Warshaw, R. (1985). Asbestos disease in family contacts of shipyard workers. *American Journal of Public Health, 75*(6), 615–617.

Kumaqai, S., Kurumatani, N., Tsuda, T, Yorifuji, T., & Suzuki, E. (2010). Increased risk of lung cancer mortality among residents near an asbestos product manufacturing plant. *International Journal of Occupational and Environmental Health, 16*(3), 268–278.

Miller, A. (2005). Mesothelioma in household members of asbestos-exposed workers: 32 United States cases since 1990. *American Journal of Industrial Medicine, 47*(5), 458–462.

Millette, J.R., & Hays, S.M. (1994). *Settled asbestos dust sampling and analysis* (pp. 59–65). Boca Roton, FL: Lewis Publishers.

National Center for Appropriate Technology. (2010). *Montana asbestos-safe weatherization demonstration project—final report.* Retrieved from www.ncat.org/special/reach.php

National Institute for Occupational Safety and Health. (1994). *Asbestos and other fibers by PCM: 7400* (4th ed.). Retrieved from http://www.cdc.gov/niosh/nmam/pdfs/7400.pdf

National Institute for Occupational Safety and Health. (1995). *Report to congress on workers' home contamination study conducted under the Workers' Family Protection Act* (Publication No. 95-123). Cincinnati: Department of Health and Human Services.

Pan, X.L., Day, H.W., Wang, W., Beckett, L.A., & Schenker, M.B. (2005). Residential proximity to naturally occurring asbestos and mesothelioma risk in California. *American Journal of Respiratory and Critical Care Medicine, 172*(8), 1019–1025.

Pardee, J.T., & Larsen, E.S. (1929). Deposits of vermiculite and other minerals in the Rainy Creek District near Libby, Montana. *United States Geological Services Bulletin, 805,* 17–28.

Peretz, A., Van Hee, V.C., Kramer, M.R., Pitlik, S., & Keifer, M.C. (2008). Pleural plaques related to "take-home" exposure to asbestos: An international case series. *International Journal of General Medicine, 1,* 15–20.

Reid, A., Berry, G., de Klerk, N., Hansen, J., Heyworth, J., Ambrosini, G., Fritschi, L., Olsen, N., Merler, E., & Musk, A.W. (2007). Age and sex differences in malignant mesothelioma after residential exposure to blue asbestos (crocidolite). *Chest, 131*(2), 376–382.

Sider, L., Holland, E.A., Davis, T.M., Jr., & Cugell, D.W. (1987). Changes on radiographs of wives of workers exposed to asbestos. *Radiology, 164*(4), 723–726.

State of Montana Department of Quality Permitting and Compliance Division Waste and Underground 80 Tank Management Bureau Asbestos Control Program. (2005). *Montana asbestos work practices and procedures manual.* Helena, MT: Author.

U.S. Environmental Protection Agency. (2003). *Final draft: Pilot study to estimate asbestos exposure from vermiculite attic insulation.* Springfield, VA: Versar.

U.S. Environmental Protection Agency. (2004). *Research method for sampling and analysis of fibrous amphibole in vermiculite attic insulation* (U.S. EPA Doc. No. 600/R-04/004). Retrieved from http://www.epa.gov/asbestos/pubs/vairesearchmethodfinal.pdf

U.S. Environmental Protection Agency. (2011a). *Additional frequent questions on vermiculite.* Retrieved from http://www.epa.gov/asbestos/pubs/verm_questions2.html

U.S. Environmental Protection Agency. (2011b). *U.S. EPA's asbestos cleanup activities.* Retrieved from http://www.epa.gov/region8/superfund/libby/cleanup.html

Whitehouse, A.C. (2004). Asbestos-related pleural disease due to tremolite associated with progressive loss of lung function: Serial observation in 123 miners, family members, and residents of Libby, Montana. *American Journal of Industrial Medicine, 46*(3), 219–225.

Zalac, F. (2003, February 7). *Deadly dust.* The National, CBC News. Retrieved from http://www.sterlingiaq.com/photos/1049134528.pdf