Summary Report

Exposure to Asbestos-Containing Vermiculite from Libby, Montana, at 28 Processing Sites in the United States

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Photographer: Unknown

Prepared by

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Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

The Agency for Toxic Substances and Disease Registry (ATSDR), based in Atlanta, Georgia, is a federal public health agency of the U.S. Department of Health and Human Services. ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances.

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Terms and abbreviations

Term or Abbreviation	Definition
Amphibole	One of two groups of silicate minerals that can form asbestiform fibers (the other group is serpentine). The form and structure (morphology) of amphibole minerals can vary from blocky particles to needle-like fibers.
Asbestiform	Refers to the unusual crystallization habit (a mineralogical term meaning appearance or form) of a mineral when the crystals are thin, hairlike fibers that are separable into thinner fibers and ultimately into fibrils. This habit accounts for greater flexibility and higher tensile strength than other habits of the same mineral. The fibers of asbestos are good examples of the asbestiform habit.
Asbestos	ATSDR uses the term *asbestos* in this report to refer to all serpentine and amphibole mineral forms that are of health concern because they are known or suspected (based on mineralogical or morphological characteristics) to be associated with asbestos-related diseases and conditions such as asbestosis, mesothelioma, lung cancer, and pleural abnormalities. Outside of this report, the definition of asbestos can vary, depending on the context. In some contexts, asbestos is referred to as a commercial term limited to six different minerals developed for commercial purposes based on their unique properties of high tensile strength, flexibility, and thermal stability. These six minerals included chrysotile, crocidolite, amosite, and the fibrous forms of tremolite, actinolite, and anthophyllite. Chrysotile belongs to the serpentine mineralogical group. The other five belong to the amphibole mineralogical group. It is important to recognize that this commercial definition of asbestos is narrow and does not include all of the serpentine and amphibole minerals that may be of health concern. Some regulatory definitions for asbestos likewise focus narrowly on the six minerals identified above (EPA 1987, OSHA 1994). Other statutory or regulatory programs, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) regulations under which the US Environmental Protection Agency (EPA) investigated and remediated the sites addressed in this report, employ a broader definition of asbestos not limited to the six commercial types (see EPA listing of asbestos as a CERCLA hazardous substance, 40 CFR 302.4). Note that amphibole minerals prevalent in the Libby mine, while historically characterized as a form of tremolite for industrial and regulatory purposes, have more recently been characterized as including the minerals winchite and richterite when analyzed under non-regulatory

	analytical techniques and under different International Mineralogical Association criteria (Meeker 2003, Leake 1997).
ATSDR	Agency for Toxic Substances and Disease Registry
Bulk material	A distinct mass or portion of matter. In the context of this report, *bulk material* often refers to a distinct mass or portion of vermiculite concentrate.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EPA	US Environmental Protection Agency
Exfoliation	In the context of this report, *exfoliation* refers to a commercial process where vermiculite is heated until it expands into low-density, accordion-like nuggets.
Exposure pathway	The route a substance takes from its source to its end point and how people can come into contact with or get exposed to it. An exposure pathway has five parts: a source of contamination; an environmental medium and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching); and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Libby amphiboles	The characteristic composition of asbestos minerals, including winchite, richterite, and tremolite, found commingled with the vermiculite mined in Libby.
MDH	Minnesota Department of Health
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PCM	Phase contrast microscopy
PLM	Polarized light microscopy
PEL	Permissible exposure limit. PELs established by OSHA are regulatory limits on the amount or concentration of a substance in the air in occupational settings. OSHA established two PELs for asbestos: the PEL for an 8-hour time-weighted average (TWA) exposure is 0.1 fibers per cubic centimeter (f/cc) of air, and the PEL for a short-term exposure is 1.0 f/cc as averaged over a sampling period of thirty (30) minutes.
TEM	Transmission electron microscopy

TRW	Technical Review Workgroup. The TRW is an EPA workgroup convened "… to support and promote consistent application of the best science in the field of risk assessment for metals and asbestos at contaminated sites nationwide. The TRW is composed of several committees: Lead Committee, Arsenic Committee, Asbestos Committee, and Bioavailability Committee." (http://www.epa.gov/superfund/health/contaminants/lead/trw.htm)
US BOM	United States Bureau of Mines
USGS	United States Geological Survey
Vermiculite	A group of hydrated silicate minerals that resemble mica. When heated, water molecules between the platy layers of the mineral structure vaporize and the vermiculite expands into accordion-like nuggets in a process referred to as "exfoliation".
Vermiculite concentrate	Vermiculite that has been mined, cleaned, and milled into various sizes, or grades.
Vermiculite ore	Vermiculite that has been removed from the ground (mined), but not yet cleaned and milled into a concentrated form.
VC	Vermiculite concentrate

Executive summary

Introduction

This report summarizes what the Agency for Toxic Substances and Disease Registry (ATSDR) and state health department partners learned during their evaluations of 28 sites that received asbestos-containing vermiculite from a mine in Libby, Montana. These 28 site evaluations focused on potential past, current, and future pathways of exposure to the asbestos associated with vermiculite from the Libby mine. Most of the processing facilities at these sites operated for different time periods in the past, during the 1920s to the early 1990s.

ATSDR began evaluating Libby-related vermiculite sites in response to documented asbestos-related health effects in Libby, Montana, and at the request of the U.S. Environmental Protection Agency (EPA). ATSDR evaluated some of the 28 sites itself, while others were evaluated in collaboration with state health departments.

Purpose and intended audience

The purpose of the report is (1) to summarize what we learned during detailed site evaluations, and (2) to provide recommendations that local, state, and federal agencies can use to address similar sites. ATSDR wrote the report for public health and environmental professionals involved with sites that received vermiculite from the Libby mine.

Terminology

In the report, ATSDR uses the term *asbestos* to refer to all serpentine and amphibole minerals, including winchite and richterite, that are of health concern because they are known or suspected to be associated with asbestos-related diseases and conditions such as asbestosis, mesothelioma, lung cancer, and pleural abnormalities. The terms *amphiboles* and *Libby amphiboles* also are used in reference to the specific asbestos minerals characteristic of the Libby mine. *Vermiculite concentrate (VC)* refers to vermiculite that has been mined, cleaned, and milled into various sizes.

Background Libby, Montana

In 2002, ATSDR reported that asbestosis mortality rates in the Libby community were 40 to 80 times higher than expected and that lung cancer mortality was 20% to 30% higher than expected. Most of the asbestosis cases identified were either former employees of the Libby mine and processing facilities or household contacts of these employees. A recently published study by scientists at the National Institute for Occupational Safety and Health (NIOSH) reported that asbestosis mortality among a cohort of 1,672 Libby vermiculite workers was 165 times higher than expected. The study also documented 15 mesothelioma deaths for this occupational cohort.

The Libby mine operated from the 1920s to 1990. By analyzing historical records, EPA identified 245 sites within the United States that may have received shipments of asbestos-containing VC from the mine.

Health effects of exposure to asbestos

Health effects associated with breathing asbestos include non-cancer respiratory effects (such as asbestosis), mesothelioma (a rare type of cancer of the membrane that encases the lungs and lines body cavities), and lung cancer.

Selection of the 28 sites

ATSDR selected sites for detailed evaluation on the basis of the following criteria: (1) EPA mandated further action at the site because they identified current contamination, or (2) the site was an exfoliation facility that processed more than 100,000 tons of VC from the Libby mine. Twenty-seven of the 28 sites that ATSDR studied were exfoliation facilities that processed vermiculite by heating it until it expanded or popped.

Data sources used for this report

ATSDR published a report about each of the 28 sites. These reports, which are available on the Internet[1], are the primary data sources for this report. Other sources include company records, existing environmental data, and reports from federal and state agencies.

Overview of primary conclusions

On the basis of the site investigations, ATSDR reached three primary conclusions about exfoliation sites and one primary conclusion about non-exfoliation sites that received VC from the Libby mine.

Conclusion (1)

ATSDR identified these three groups of people who experienced significant exposure to asbestos (specifically Libby amphiboles) associated with facilities that exfoliated vermiculite:

- Former employees,
- Household contacts of former employees, and
- Some community members, particularly children, who had frequent, direct contact with VC or waste rock from these facilities.

These groups were exposed to asbestos in the past, when the facilities actively were exfoliating VC from Libby. They likely have increased risk for developing both carcinogenic and non-carcinogenic asbestos-related diseases. Actual health risks for individuals would vary according to a number of factors, including frequency, duration, and intensity of exposure to asbestos, size and type of asbestos to which one was exposed, personal risk factors (smoking, history of lung disease, and genetic susceptibility), age at initial exposure, and use and effectiveness of personal protective equipment (for workers).

Recommendation for conclusion (1)

Increase awareness about exposure to asbestos associated with past vermiculite exfoliation operations among (1) people who experienced significant exposure to asbestos associated with exfoliation facilities, (2) health care providers, and (3) public health and environmental professionals. Suggested activities:

- ATSDR and state health departments should continue to provide

[1] Internet link: http://www.atsdr.cdc.gov/asbestos/sites/national_map/

health education materials to persons who self-identify as having been exposed to asbestos associated with vermiculite exfoliation. The many challenges to identifying and locating exposed persons may limit active outreach efforts. Exposed persons should be encouraged to discuss their exposure with their health care providers.

- Consider the efficacy of localized outreach strategies for communities surrounding former exfoliation sites to create opportunities for self-identification among former workers and other exposed groups. Such an effort may not be justified for communities where significant demographic changes occurred after the local vermiculite exfoliation facility closed.
- Promote ATSDR self-instructional publications, including *Case Studies in Environmental Medicine: Asbestos Toxicity* and *ATSDR Environmental Medicine Grand Rounds: Asbestos Toxicity*[2], as tools for informing pulmonologists and other health care providers about occupational and non-occupational exposure to asbestos associated with past vermiculite exfoliation operations.
- Integrate information about asbestos-containing VC into existing guidance for asbestos-related health care and into existing occupational, medical, and environmental literature, book chapters, conferences, peer-reviewed journals, and other publications.

Conclusion (2)

The findings from evaluations of 27 exfoliation facilities[3] (most of which operated in the past) suggest that residual asbestos in the form of Libby amphiboles may be present in ***indoor settled dust*** at many of the other 78 sites identified as former exfoliation facilities. Many of these facilities currently are being used for other, non-exfoliation commercial or industrial operations.

EPA site assessment and sampling data from 2000–2005 for interior areas at 27 exfoliation sites indicate:

- Sampling data were available for 20 of the 27 exfoliation sites.
- Sampling results prompted interior cleanup at 11 sites.
- Sampling data were not available for indoor areas at 7 sites.
- The number and type of samples collected, the analytical methods, and the decision-making framework used to evaluate indoor areas varied.
- The primary source of potential exposure in indoor spaces was residual asbestos in settled dust.

Note that because these 27 sites were not selected randomly from the group of known former exfoliation sites, they may have been more likely to have residual Libby amphiboles in indoor settled dust.

[2] Both items are available at http://www.atsdr.cdc.gov/csem/asbestos/cover2.html.
[3] As previously noted, 27 of the 28 sites that ATSDR evaluated were exfoliation facilities.

Conclusion (3)

The findings from evaluations of 27 exfoliation facilities (most of which operated in the past) suggest that residual asbestos in the form of Libby amphiboles may be present in ***exterior soil*** at many of the other 78 sites identified as former exfoliation facilities. Many of these facilities currently are being used for other, non-exfoliation commercial or industrial operations.

EPA site assessment and sampling data from 2000–2005 for exterior areas at 27 exfoliation sites indicate:

- Sampling data were available for 26 of the 27 exfoliation sites.
- Sampling results prompted exterior cleanup at 15 sites.
- Sampling data were not available for exterior areas at 1 site.
- The number and type of samples collected, the analytical methods, and the decision-making framework used to evaluate exterior areas varied.
- Residual asbestos was typically found in areas where VC and waste rock were handled or stored, including rail spurs where VC was unloaded, stockpile areas, and storage silo areas.
- Waste rock was buried at three former exfoliation sites; investigations are continuing at a fourth exfoliation site where waste material was reportedly buried. Asbestos-containing material does not present a hazard as long as it is buried. However, it could become a source of exposure during future site development or excavation activities.

Note that because these 27 sites were not selected randomly from the group of known former exfoliation sites, they may have been more likely to have residual Libby amphiboles in exterior soil.

Recommendations for conclusions (2) and (3)

Evaluate existing site information and sampling data for all exfoliation facilities, using a consistent investigative and decision-making framework to identify and eliminate or reduce current exposures to asbestos that pose an unacceptable risk. Action levels and clean-up standards should be relevant to Libby amphiboles and should incorporate site-specific factors, including current land and building uses.

- Review existing site inspection and sampling data for all exfoliation sites, using a consistent investigative and decision-making framework; refer to guidance from EPA's Technical Review Workgroup (TRW) Asbestos Committee.
- Ensure that existing visual inspection and environmental sampling data are adequate to assess the following material handling areas in particular: rail spur areas where VC was unloaded, indoor building spaces where exfoliation occurred, VC and waste rock storage areas, and areas where waste rock may have been buried or placed.
- Collect additional environmental samples at these sites as needed to identify current exposures to residual asbestos in the form of Libby amphibole contamination.

- Eliminate or reduce current exposures to asbestos that pose an unacceptable risk.

Conclusion (4)

ATSDR did not conduct a detailed review of non-exfoliation sites. These factors suggest that follow-up activities at non-exfoliation sites may not be warranted, or should be a lower priority than those at exfoliation sites:

- Overall, non-exfoliation sites received less than 5% of the VC shipped from Libby during 1964 until the early 1990s.
- ATSDR gathered incidental information indicating that many of these facilities received relatively small quantities of VC; the VC was shipped in closed bags rather than in bulk via rail cars; and processing methods used the VC in the condition in which it arrived, instead of expanding it, as was done in exfoliation.
- According to EPA summary reports, none of the non-exfoliation sites visited by EPA during 2000–2002 required cleanup on the basis of the presence of residual Libby amphiboles.

Recommendation for conclusion (4)

Non-exfoliation sites should not be broadly targeted for follow-up activities. However, some of these sites may require further review or investigation on a case-by-case basis.

Who will implement the recommendations?

The recommendations are intended as a general framework for follow-up activities. They may be implemented by many different entities, including site owners and local, state, and federal agencies. The number and variety of sites, stakeholders, public health and regulatory organizations, and jurisdictions involved suggest that a cooperative and flexible approach is necessary to effectively identify and implement follow-up actions appropriate for individual sites.

What is ATSDR's role in implementing these recommendations?

ATSDR acts in an advisory, nonregulatory capacity, working with communities, environmental groups, and local, state, and other federal groups to protect public health. ATSDR's role in supporting the recommendations in this report will vary from providing technical assistance to participating in implementation. Senior ATSDR scientists are part of EPA's TRW Asbestos Committee, and ATSDR is committed to providing technical support on asbestos issues through this collaborative effort.

ATSDR has initiated or supported many activities to understand better the potential public health effects at sites that processed asbestos-containing vermiculite. Some of these activities include worker studies, community surveys and screenings, and disease-specific surveillance. These projects are progressing independently, and their findings will be published in separate reports.

Purpose and intended audience for this report

This report describes one aspect of ATSDR's overall response to a request from the U.S. Environmental Protection Agency (EPA) to examine potential public health impacts at sites that received asbestos-containing vermiculite concentrate (VC)[4] from a mine in Libby, Montana. The purpose of the report is (1) to summarize what we have learned during detailed site evaluations at 28 sites, and (2) to provide information and practical recommendations that federal, state, and local agencies can use to address similar sites. This report is intended for public health and environmental regulatory professionals involved with sites that received asbestos-containing vermiculite.

Statement of issues

Several hundred locations across the United States received shipments of asbestos-containing VC from the mine in Libby, Montana during the 1920s–1990. Given the scope of documented exposure pathways and the prevalence of asbestos-related health effects in the Libby community, many public health questions about sites that received VC from the Libby mine have arisen. ATSDR defined two issues for site-specific investigations.

- Whether there is (or was) significant human **exposure to asbestos** associated with the VC from Libby, Montana.
- Whether there are significant increases in **asbestos-related health effects** in communities around sites that received VC from Libby, Montana.

This report explores the first of these two questions. Separate ATSDR publications will address investigations into health effects that may be apparent in communities around these sites. For context, ATSDR's overall approach to both questions is described in subsequent paragraphs.

ATSDR's overall approach

During 2000–2002, EPA regional offices conducted preliminary and/or detailed site assessments at over 200 locations they identified as having received VC from the Libby mine. In the fall of 2002, ATSDR selected 28 sites for detailed evaluation of potential past, current, or future pathways of exposure to asbestos associated with VC from Libby. Individual reports for each of the 28 sites are available on the Internet.[5] This report represents a summary of what ATSDR learned about exposure pathways from the 28 site investigations. In this report, ATSDR also proposes recommendations for various follow-up activities at sites that received VC from the Libby mine. Many of these recommendations are directed toward environmental and public health partners at the federal, state, and local level. ATSDR's role in supporting the recommendations will vary from providing technical assistance to participating in implementation.

Beginning in the summer of 2002, ATSDR worked with a number of state health departments to investigate asbestos-related health effects by examining existing health statistics (cancer registry and mortality data) for communities surrounding sites that received VC from Libby. This effort encompassed nearly 100 sites in 25 states. All 28 sites for which ATSDR completed detailed

[4] Vermiculite concentrate (VC) refers to the vermiculite after it has been mined, cleaned, and milled in Libby.
[5] The individual reports are available at http://www.atsdr.cdc.gov/asbestos/sites/national_map/.

exposure evaluations also were included in the health statistics review. The health statistics findings for a few of the 28 sites are included in the individual site reports posted on the Internet. The findings for most of the sites were published recently in a summary journal article [Horton et al. 2008]. Other related projects initiated or supported by ATSDR include:

- a disease progression study of former workers from a vermiculite processing site in Ohio;
- assessment of the prevalence of asbestos-related health conditions among former workers and their household contacts at selected vermiculite processing sites in Arizona, California, New Jersey, Ohio, and Minnesota;
- assessment of the prevalence of asbestos-related health conditions within a community, including a cohort of people who as children played in vermiculite waste rock piles, at a site in Minnesota; and
- pilot mesothelioma surveillance projects in New Jersey, New York, and Wisconsin.

Again, the findings from these projects will be published independently, as they are completed.

Selection criteria and scope of the 28 site evaluations

From an EPA list of 245 domestic sites that may have received shipments of asbestos-containing VC from the Libby mine (EPA, unpublished data, 2003)[6], ATSDR selected 28 sites for detailed review on the basis of the following criteria:

- The EPA mandated further action or investigations at the site because they identified current contamination, or
- The site was an exfoliation facility that processed more than 100,000 tons of VC from the Libby mine. Exfoliation, a processing method in which VC is heated and expanded (or "popped"), is expected to have released more asbestos than other processing methods.

The 28 selected sites (Figure 1, Table 1) encompass 25 former vermiculite exfoliation sites, 2 current exfoliation sites, and 1 former gypsum board manufacturing site. Most of these facilities operated for different time periods in the past, during the 1920s to the early 1990s. ATSDR was the lead public health agency in evaluating 14 of the sites and state health departments were the lead,

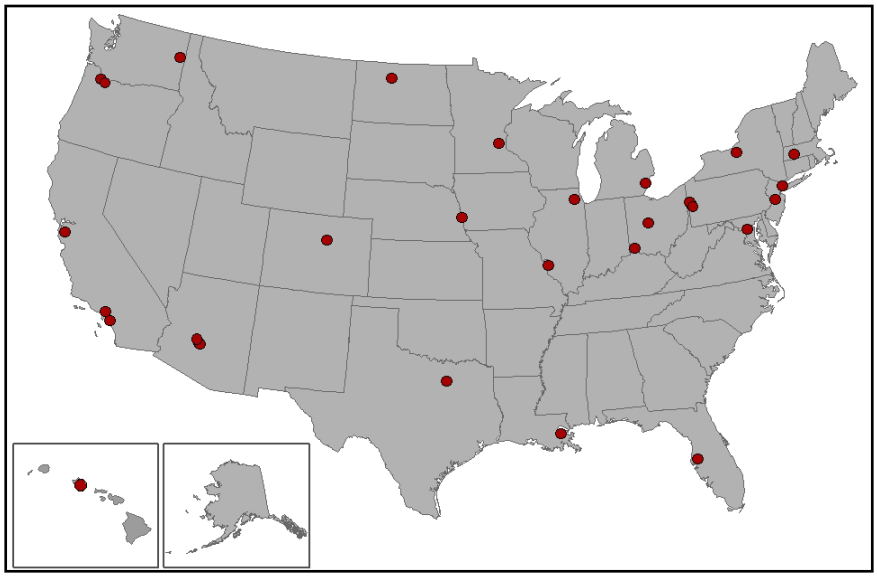

Figure 1. Twenty-eight sites that ATSDR evaluated.

[6] EPA developed this list of sites over time. The list that ATSDR used, dated April 24, 2003, contains 245 sites.

under a cooperative agreement with ATSDR, at the other 14 site evaluations.

The site evaluations address potential past, current, or future pathways of exposure to asbestos associated with vermiculite from Libby. The objectives of the evaluations were to (1) identify ways people could have been exposed to asbestos at the sites in the past and ways that people could be exposed now or in the future, and (2) determine whether the exposures represent a public health hazard. Assessing potential exposure to asbestos through commercial or consumer use of company products (e.g., vermiculite attic insulation, agricultural products) that contain vermiculite from Libby is outside the scope of the project.[7]

Background

Libby, Montana

Vermiculite and asbestos minerals occur in geologic formations in many parts of the world. The Vermiculite Mountain (also called Zonolite Mountain) deposit in Libby, Montana, contains both minerals commingled in the same geologic formation. As a result, the vermiculite that was commercially mined, cleaned, concentrated, milled, and shipped from Libby during the 1920s–1990 contained various amphibole minerals in fibrous and fiber-like forms.

The U.S. Geological Survey describes vermiculite as "… a general term applied to a group of platy minerals that form from the weathering of micas by ground water. Their distinctive characteristic is a prominent accordion-like unfolding and expansion when heated …" [USGS 2002]. The vermiculite ore[8] retrieved from the mine contained up to 26% amphibole minerals before it was concentrated and milled in Libby to produce different sizes, or grades, of VC [Atkinson 1982]. The various grades of milled VC shipped from Libby contained asbestos at concentrations ranging from 0.3% to 7.0% [Atkinson et al. 1982].

Before the Libby mine closed in 1990, it supplied VC to several hundred sites in the United States. Most of the VC shipped to these domestic facilities was commercially exfoliated, a process that uses intense heat to vaporize water molecules in the layers of vermiculite and expand it into low-density, accordion-like nuggets. Expanded vermiculite is used as lightweight aggregate and thermal insulation in building materials, as loose-fill insulation, and as a soil conditioner and fertilizer carrier in agricultural products [BOM 1990].

People who worked in the Libby mine and local processing facilities and many people who lived in the Libby community were exposed to asbestos [Amandus et al. 1987a, 1987b, 1987c; McDonald et al. 1986; Peipins et al. 2003]. A recently published study by scientists at the National Institute for Occupational Safety and Health (NIOSH) reported that asbestosis mortality among a cohort of 1,672 Libby vermiculite workers was 165 times higher than expected [Sullivan 2007]. The study also documented 15 mesothelioma deaths for this occupational cohort. Nearly 18% of over 7,300 people who participated in a community-based medical screening program and underwent chest radiographs in Libby had radiographic pleural abnormalities consistent with asbestos exposure [Peipins et al. 2003]. The prevalence of pleural abnormalities was associated with the number of reported exposure pathways, ranging from 6.7% for those who reported no apparent exposure to 34.6% for those who reported 12 or more

[7] EPA, ATSDR, and the National Institute for Occupational Safety and Health (NIOSH) developed a fact sheet for consumers of vermiculite products. This fact sheet is available at http://www.epa.gov/asbestos/pubs/verm.html.
[8] Vermiculite ore refers to the mined vermiculite before it is cleaned, concentrated, and milled into VC.

pathways of exposure to asbestos. Pleural abnormalities were noted in 51% of the 365 study participants who were workers at the mine and associated facilities. A mortality review for the Libby community revealed significantly elevated standardized mortality rates for asbestosis (40 to 80 times higher than expected) and lung cancer (20% to 30% higher than expected) [ATSDR 2002]. Mesothelioma mortality was also elevated for the 20-year study period (1979 to 1998), but only a small number of cases were identified for this time period [ATSDR 2002]. The majority of asbestosis and mesothelioma cases identified were either former employees of the Libby mine and processing facilities or their household contacts.

Mineralogical and analytical considerations

Asbestos minerals are silicates, meaning their crystalline structure is based on silicon-oxygen tetrahedra. Many other elements, such as aluminum, calcium, iron, magnesium, potassium, and sodium, also can be present within the mineral structure in varying amounts. Asbestos minerals are categorized into two main groups, serpentine and amphibole. Chrysotile, the predominant type of asbestos mineral used commercially, is a member of the serpentine group. Chrysotile has relatively long and flexible crystalline fibers. Fibrous amphibole minerals are often more brittle and can have a rod- or needle-like shape.

It is important to note that some (but not all) federal and state regulations define “asbestos” to include only the most common forms of asbestos used in building products and other commercial items: chrysotile, crocidolite, amosite, and the fibrous varieties of tremolite, actinolite, and anthophyllite. The Occupational Safety and Health Administration (OSHA) defines asbestos this way in its health standards for asbestos used in various industries (29 CFR 1910.1001, 1915.1001, and 1926.1101). EPA defines asbestos this way in the Asbestos Hazard Emergency Response Act for managing asbestos in schools and in the National Emissions Standards for Hazardous Air Pollutants provisions of the Clean Air Act [EPA 1987; EPA 1990]. In contrast, EPA lists asbestos as a "hazardous substance" under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) by reference to its broad Chemical Abstracts Service (CAS) registry classification that is not limited to the six commercial mineral types (40 CFR 302.4). EPA's investigation and remediation of the Libby site and the vermiculite processing sites addressed in this report was conducted under the authority of CERCLA.

Vermiculite from Libby contains several varieties of amphiboles. The analytical method and scientific nomenclature applied determines how these amphiboles are defined. While Libby amphiboles historically have been classified as a form of tremolite from an industrial, regulatory, and scientific perspective, more recent non-regulatory analyses utilizing criteria adopted by the International Mineralogical Association [Leake et al. 1997] have classified the Libby amphiboles as containing winchite, richterite, and tremolite [Meeker et al. 2003]. On the basis of recent analyses by scientists from the U.S. Geological Survey (USGS), most of the respirable fraction of asbestos from Libby can be classified under the non-regulatory IMA/Leake criteria as winchite and richterite [Meeker et al. 2003]. In this report, the term *Libby amphibole* is used to refer to the characteristic composition of amphibole minerals found commingled with the vermiculite mined in Libby. As mentioned previously, some regulatory definitions of asbestos do not include the amphiboles winchite and richterite, as defined by Leake et al. [1997], that are predominant in the Libby formation.

Individual asbestos fibers and particles are microscopic, but these minerals are often visible when many fibers form together in “bundles”. The same minerals that grow in fibrous form

typically also develop in nonfibrous blocky or prismatic form. Asbestos particles do not have any detectable odor or taste. They do not dissolve in water or evaporate into the air, although individual fibers easily can be suspended in the air. They are resistant to heat, fire, and chemical and biological degradation, thus they can remain virtually unchanged in the environment for a long time [ATSDR 2001b].

Measuring asbestos in environmental media (air, soil, and dust) is complicated. Concentration, mineralogy, and size (length and width) are all significant factors in determining possible health effects from exposure to asbestos fibers or particles. However, analytical techniques vary greatly in their ability to detect and characterize these parameters. Other considerations such as sample collection and preparation, counting rules (what fiber lengths and aspect ratios are counted, how groups of fibers and other particles are defined and counted), and regulatory definitions also affect asbestos measurement and reporting.

Phase contrast microscopy (PCM) and transmission electron microscopy (TEM) are the analytical techniques typically used to characterize asbestos in air samples. For soil, dust, or bulk material samples, polarized light microscopy (PLM) is often used, although TEM and SEM techniques can also be employed. Light microscopy techniques (PCM and PLM) have several limitations, including their inability to detect fibers thinner than 0.25 micrometers (µm) in diameter. PCM techniques generally do not distinguish between asbestos and nonasbestos fibers. Many different analytical methods exist for asbestos analysis; these methods specify not only the analytical technique (such as PCM or TEM), but also the sample preparation, counting rules, and reporting scheme to be used by the analyst.

Libby amphiboles present several unique analytical challenges, described thoroughly in a publication by USGS [Meeker et al. 2003]. On the basis of their analyses, Meeker et al. found that Libby amphiboles are morphologically variable, ranging from blocky, prismatic particles to long, needle-like asbestiform fibers (Figure 2). Libby amphiboles also can vary in specific chemical composition between fibers or even along the same fiber, grading, for example, from tremolite on one end of the fiber to winchite on the other end of the fiber. According to Meeker and his colleagues, "…none of the present regulatory analytical methods (with the possible exception of well-calibrated SEM/EDS[9] analysis using calibrated standards similar to EPMA/WDS[10]) can accurately differentiate the amphiboles present in the asbestiform material from Vermiculite Mountain" [Meeker et al. 2003]. These analytical methods are not used commonly during site characterizations.

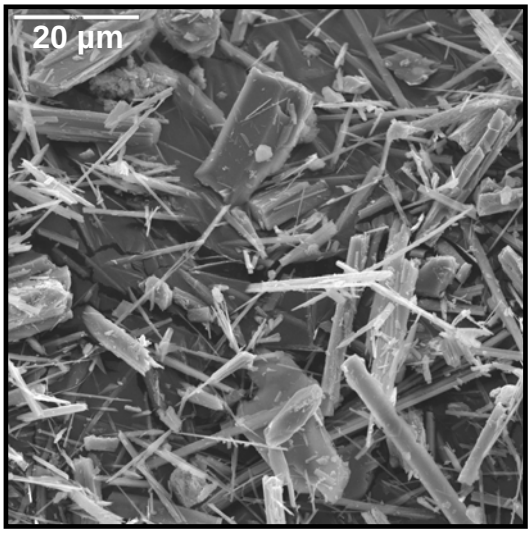

Figure 2. Scanning electron microscope image of Libby amphiboles courtesy of USGS.

[9] Scanning electron microscopy combined with energy dispersive x-ray spectroscopy (SEM/EDS).
[10] Electron probe microanalysis (EPMA) using wavelength dispersive spectroscopy (WDS).

Health effects

ATSDR considers the inhalation route of exposure to asbestos to be the most significant in the current evaluation of sites that received VC from Libby. Although oral ingestion and dermal exposure routes may exist, health risks from these exposures are low compared to health risks from the inhalation route [ATSDR 2001b]. Ingestion of asbestos causes little or no risk of noncancer effects [ATSDR 2001b]. Some evidence suggests that acute oral exposure can induce precursor lesions of colon cancer and that chronic oral exposure can lead to an increased risk of gastrointestinal tumors [ATSDR 2001b]. However, a recently published review of studies involving selected cancer sites concluded that the evidence is suggestive but not sufficient to allow inference of a causal relationship between oral exposure to asbestos and stomach and colorectal cancer [IOM 2006]. Health effects associated with breathing asbestos include the following:

- *Non-cancer effects*—these include *asbestosis,* scarring of the lung caused by asbestos lodged in the lung; *pleural plaques,* localized areas of thickening of the pleura; diffuse *pleural thickening,* extensive, non-discrete thickening of the pleura; *pleural calcification,* calcium deposition in pleural areas thickened from chronic inflammation and scarring; and *pleural effusions,* fluid accumulation in the pleural space between the lungs and the chest cavity [ATSDR 2001b]. Loss of lung function or other clinical signs and symptoms may or may not be associated with these noncancer effects.
- *Mesothelioma*—Cancer of the membrane (pleura) that encases the lungs and lines the chest and peritoneal cavity. This cancer can spread to tissues surrounding the lungs or other organs. The majority of mesothelioma cases are attributable to asbestos exposure [ATSDR 2001b].
- *Lung cancer*—Cancer of the lung tissue, specifically bronchogenic carcinoma. The exact mechanism relating asbestos exposure to lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk of developing lung cancer [ATSDR 2001b].
- *Laryngeal cancer*—Cancer of the larynx (voice box). A recent review of numerous studies involving selected cancer sites concluded that there is sufficient evidence to suggest a causal relationship between asbestos exposure and laryngeal cancer [IOM 2006].

The latency period for noncancer respiratory effects is usually 15–40 years from the time of initial exposure to asbestos. For lung cancer and mesothelioma, the latency periods are generally 20–30 years or more [ATSDR 2001b, Lanphear and Buncher 1992].

Exposure to asbestos does not necessarily mean a person will develop asbestos-related health effects. In general, increasing frequency, duration, and intensity of exposure are associated with increased risk of disease. Personal risk factors such as a history of smoking, a history of lung disease, and genetic susceptibility are important determinants of the actual risk [ATSDR 2001b].

The mineralogy and size of the fibers involved in the exposure are also important in determining the likelihood and the nature of potential health impacts. Several epidemiological studies have shown that amphiboles are more toxic than chrysotile [ATSDR 2001b; McDonald and McDonald 1997; EPA 2003]. Some (but not all) regulatory definitions of asbestos do not include

the amphiboles winchite and richterite. However, winchite and richterite are widely considered to have the same toxicity as the regulated amphiboles [EPA 2003]. Exposure to amphiboles that are long (greater than 10 μm) increases the risk of mesothelioma and lung cancer [ATSDR 2001b; EPA 2003]. Short amphibole fibers (less than 5 μm) are thought to be less important in inducing carcinogenic effects, but they may play a role in increasing the risk of non-cancer effects such as asbestosis [ATSDR 2003b]. Fiber diameters greater than 1 to 3 μm are considered above the upper limit of respirability (that is, too large to inhale deep into the lungs) and thus do not contribute significantly to risk [EPA 2003; EPA 1994].

Chronic exposure is a significant risk factor for asbestos-related disease. However, in some instances, brief episodic exposures may also contribute to disease. A brief, high-intensity exposure from working two summers at a vermiculite exfoliation facility in California has been linked to a case of fatal asbestosis [Wright et al. 2002]. Very little conclusive evidence is available regarding the health risks of low-level, intermittent exposures to asbestos. Projects recently initiated by EPA, NIOSH, and ATSDR will contribute valuable scientific information about such exposures (EPA 2007a, EPA 2007b, NIOSH 2008, ATSDR 2008).

Asbestos is a known carcinogen [NTP 2005; EPA 2005a]. The current EPA toxicological model used to describe carcinogenic health risks due to asbestos exposure was based on epidemiological studies involving chrysotile and amphibole exposure and sample quantification techniques that were limited in their analytical capabilities.[11] This model has significant limitations, including the fact that it does not consider mineralogy or fiber size distribution and it combines both lung cancer and mesothelioma risk into one slope factor. EPA is in the process of updating its risk methodologies for asbestos to include mineralogical and fiber length distribution information.

An adequate toxicological model that describes the risks of noncarcinogenic health effects from asbestos exposure currently does not exist. EPA recently appointed an internal group to address this need.

Identification of sites that received VC from the Libby mine

ATSDR reviewed several sources of information pertaining to sites that may have received VC from the Libby mine. Early EPA lists of locations that may have received VC from Libby included over 500 addresses. EPA refined these initial address lists over time to exclude billing addresses (versus actual processing or handling sites) and addresses that could not be field-verified. The last refinement of the list, dated April 24, 2003, encompasses 245 sites.

ATSDR used the EPA list of 245 sites as a baseline to identify known exfoliation sites. Sources of information included EPA summary information from past U.S. Bureau of Mines (BOM)/USGS mineral reports, historical BOM/USGS Minerals Yearbook information, EPA and ATSDR trip reports, W.R. Grace records for licensees and independent exfoliation companies, and limited Internet research. ATSDR also received supplemental information from EPA on June 30, 2008, that identified five former exfoliation facilities that were not included originally in the EPA list of 245 sites dated April 24, 2003.

[11] PCM analytical techniques, for example, cannot detect fibers less than 0.25 μm in diameter and cannot distinguish between asbestos and nonasbestos fibers.

Exfoliation facilities that may have received VC from Libby

On the basis of available information, ATSDR estimates that 105 sites exfoliated VC from Libby (Appendix A). Note that 100 of these sites were identified from EPA's list of 245 sites, dated April 24, 2003. The other 5 former exfoliation facilities were recently identified by EPA (EPA, unpublished information, 2008). These 105 sites consist of current and former exfoliation facilities as well as other industrial sites that exfoliated VC for use in their own products. Shipping invoices are available to confirm that many of these exfoliation facilities received VC from Libby in the past. However, this type of information is not available for all exfoliation sites listed.

During its investigations at the Libby mine, EPA obtained over 80,000 VC shipping invoices from W.R. Grace for the period that the company owned the mine (1964–present). An analysis of EPA's summary of these invoices indicates that a total of approximately 6,109,000 tons of VC were shipped to the 245 sites during 1964–early 1990s.[12] Using this information, ATSDR estimates that exfoliation facilities received over 95% of the VC shipped from the Libby mine to the 245 sites during 1964–early 1990s. Available invoice records corresponded to W.R. Grace's tenure as owner of the Libby mine; therefore, limited information was available about production and shipping of VC before 1964. It is important to note that the Libby mine began operations in the 1920s; therefore, more than 40 years of shipping/distribution data are missing.

Non-exfoliation facilities that may have received VC from Libby

The 145 non-exfoliation sites on EPA's list of 245 sites represent a variety of industries, including gypsum wallboard manufacturing, agricultural product manufacturing, shipping, and mining, among others. The shipping invoice summary data described above show that the 145 non-exfoliation sites received less than 5% of the VC shipped from the Libby mine to the 245 sites during 1964–early 1990s.

Summary of the site evaluations

From the EPA list of 245 domestic sites that may have received shipments of asbestos-containing VC from the Libby mine, ATSDR selected 28 sites for detailed evaluations. ATSDR and state health department partners conducted the 28 site evaluations from late 2002 through 2006. Site-specific results, conclusions, and recommendations are documented in individual reports for each of the 28 sites. These reports are available for review on the Internet (http://www.atsdr.cdc.gov/asbestos/sites/national_map) or by contacting ATSDR.[13]

Data sources

ATSDR acquired historical industrial hygiene data, including personal air samples for workers and engineering sampling data from work areas, and various operational and technical data for the sites from a database of W.R. Grace documents. EPA Region 8 obtained this document database, comprised of approximately 2.5 million electronic image files, during the investigation of the Libby mine. The database contains confidential business information and private

[12] The invoice information for these sites is inexact, and it may underestimate or overestimate the actual amount of VC received at individual sites (reference the discussion of limitations later in this report).

[13] You may contact ATSDR toll-free at 1-888-422-8737 for copies of the reports. Please mention the site name and address, including city and state (Table 1 lists this information for the 28 sites).

information that is not publicly available. Within this report, ATSDR references information from the database of W.R. Grace documents as "EPA, unpublished data, 2000".

Remedium Group, Inc., a subsidiary of W.R. Grace, provided ATSDR with documents containing historical environmental data for many of the sites. These data consisted of industrial hygiene reports, confirmation air samples collected by W.R. Grace after the company had closed and cleaned some of the sites, and waste disposal information.

EPA assembled and summarized over 80,000 W.R. Grace invoices for shipments of VC from the Libby mine to processing and handling sites across the country. These invoice records corresponded to W.R. Grace's tenure as owner of the Libby mine; therefore, limited information was available about production and shipping of VC before 1964. As previously stated, the Libby mine began operations in the 1920s; therefore, more than 40 years of shipping/distribution data are missing. ATSDR used EPA's summary of available shipping invoices for the VC tonnage figures attributed to the sites (EPA, unpublished data, 2001).

EPA is the primary source of current environmental data for the sites. EPA collected indoor air and dust samples, outdoor soil samples, and bulk material samples during many of its site investigations and site clean-up activities.[14] ATSDR also reviewed reports from NIOSH describing NIOSH's site evaluations at 10 active facilities that either expand VC or use expanded vermiculite as a product ingredient [NIOSH 2004]. NIOSH performed this work in response to a request for technical assistance from OSHA. Two of the sites NIOSH investigated were also part of the ATSDR site evaluations (Verlite Company, Tampa, Florida; The Scotts Company, LLC, Marysville, Ohio).

Other sources of data used for evaluating the sites included U.S. Census records, historical reports from the US BOM and the USGS, aerial photographs, and site visits by ATSDR and EPA. In some cases, community members, former workers, and site occupants provided anecdotal information about the sites and potential exposure pathways.

Site evaluation methodology

ATSDR's experience in Libby and at a few early investigations at vermiculite exfoliation facilities guided development of a conceptual site model for likely pathways of exposure to asbestos at the sites (Table 2). As stated previously, ATSDR considered only the inhalation route of exposure for these site evaluations.

ATSDR and state health partners researched information to confirm the presence or absence of each exposure pathway and determine its relative significance. The significance of each exposure pathway was evaluated by considering site-specific exposure data, including frequency, duration, and intensity of exposure. This evaluation is qualitative or semi-quantitative for most of the pathways because of data gaps and limitations in the available data.

Several reference levels for asbestos in air, soil, and dust are available for comparison to site-specific data (Table 3). Note that the regulations and associated regulatory levels cited in Table 3 and in the discussion that follows are provided for reference only, not as an indication that the vermiculite sites are subject to these regulations. At a given site, the level of asbestos in air, soil, and dust that is associated with an acceptable health risk for exposure depends on a number of

[14] EPA site reports are available from the EPA regional offices.

factors, including the size and type of asbestos present, the location and extent of the contaminated area, the type of activities occurring in and around contaminated areas, and human activity patterns.

Although important to show the presence or absence of Libby amphiboles, the soil and dust data available for many of these sites are of limited use for predicting potential exposures. Airborne fibers are generated when asbestos-containing soil or dust is disturbed. However, in most cases, good methods are not available to predict airborne exposure levels from measured fiber levels in soil or dust. Recent activity-based studies show that disturbing soil containing less than 1% asbestos can generate airborne fiber concentrations at or near the OSHA permissible exposure limit (PEL) of 0.1 fibers per cubic centimeter (f/cc) of air [EPA 2001; EPA 2004a]. Under EPA guidance for Superfund sites, contaminant removal or other measures may be appropriate for certain site-specific exposure scenarios to prevent airborne exposure from soil containing less than 1% asbestos [EPA 2004b].

Quantitative health risk assessments were not completed as part of the pathway evaluations for these sites. Data gaps and limitations in the available exposure assessment information restrict our ability to estimate health risks quantitatively for the pathways evaluated.

Findings about vermiculite exfoliation operations

ATSDR collected information about historical vermiculite exfoliation operations throughout the 28 site evaluations. This information provides context and important exposure information for evaluating past, present, and future pathways of exposure to asbestos at these sites. The summary of vermiculite exfoliation operations presented in the following paragraphs was derived from historical BOM reports [BOM 1933; BOM 1953] and company documents from W.R. Grace (EPA, unpublished data, 2000).[15] W.R. Grace owned and operated the Libby mine and several dozen vermiculite exfoliation facilities from 1963 to the early 1990s.

In general, vermiculite exfoliation facilities were small-scale operations employing from 10 to 50 people. The staff profile at the facilities varied, but it typically included a mixture of sales people, salaried supervisors, administrative staff, and hourly workers. At many of the sites, all facility operations were housed in a single building. Most exfoliation facilities were dedicated to vermiculite exfoliation, operating from 1 to 3 exfoliation furnaces.[16] The facilities operated from 1 to 3 shifts per day, with several of the high-volume facilities operating 3 shifts, 7 days a week. A number of distinct job categories are consistently cited in internal industrial hygiene reports from the 1970s and 1980s for the W.R. Grace exfoliation facilities: shift leader, furnace operator, bagger, maintenance, forklift operator, and mixer operator for Monokote® fireproofing material.

The key material handling and processing steps in commercial vermiculite exfoliation include delivery of VC, storage of VC, transfer of VC to the exfoliation furnace, heating and expansion of VC in the furnace, separation of expanded vermiculite from waste rock and fine material, and packaging or bulk storage of expanded vermiculite product (Figure 3) [EPA 2006a].

[15] W.R. Grace company documents that EPA Region 8 obtained during the Libby mine investigation. This database of documents contains confidential business information and private information that is not publicly available.
[16] One notable exception was the Scotts (formerly O.M. Scott) facility, which had eight exfoliation furnaces.

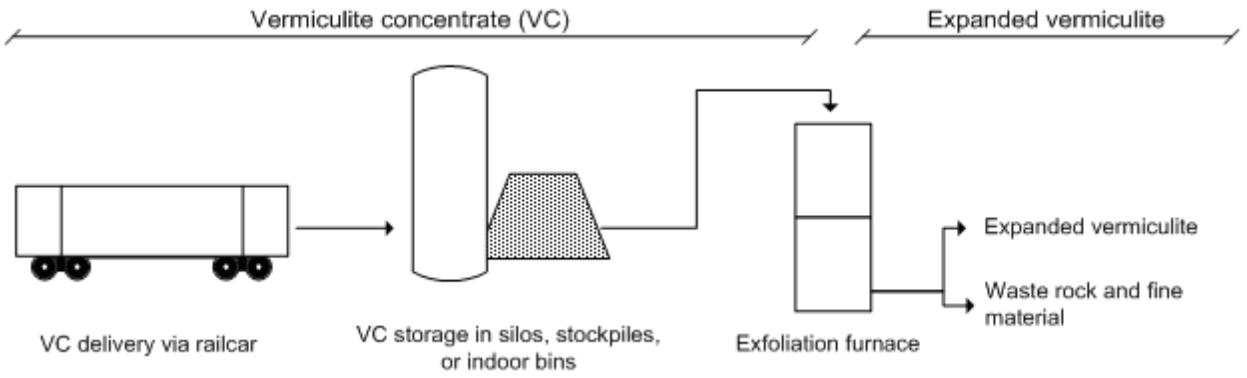

Figure 3. Generalized vermiculite exfoliation process components

W.R. Grace and previous owners of the Libby mine shipped the VC from Libby in several size grades. Grade #1 was the largest size (maximum dimension 5–10 millimeters), and grade #5 was the smallest size (maximum dimension 0.2–0.5 millimeter) [Atkinson et al. 1982]. Data from an EPA-sponsored study indicated that the different size grades of VC contained concentrations of "fibrous amphiboles" ranging from 0.3% to 7% [4%–6% (grade #1), 4%–7% (grade #2), 2%–4% (grade #3), 0.3%–1% (grade #4), and 2%–5% (grade #5)] [Atkinson et al. 1982]. The stated ranges of amphibole content in the study were from samples collected daily for 11 consecutive days in October of 1980. It should be noted that these samples may not be representative of the amphibole content of VC over the entire operating period of the Libby mine (1920s–1990).

VC typically was shipped from Libby to the exfoliation facilities in bulk by railcar. In the past, workers at these facilities used shovels and front-end loaders to unload VC manually from the railcars and store it on the site in outdoor stockpiles, enclosed silos, or indoor bins. At many of the facilities, the VC transfer processes eventually were automated with screw-type augers and conveyor belts for transport to the storage areas and into the exfoliation furnace.

Each furnace was capable of processing approximately 2,000 pounds of VC per hour (EPA, unpublished data, 2000). Furnace temperatures ranged between 1,500 degrees to 2,000 degrees Fahrenheit, based on the size, or grade, of VC processed. The exfoliation furnace(s) typically were vented to the outside air via an exhaust stack.

Commercial vermiculite exfoliation produces a waste rock material that is essentially VC that did not expand during heating in the furnace. Estimates of the amount of asbestos in the waste rock vary from 2% to 10% [EPA, unpublished data, 2000; EPA 2001]. In an internal report focusing on waste rock disposal options, W.R. Grace documented that the Beltsville, MD, facility processed 5,581 tons of VC and generated approximately 830 tons of non-expandable waste rock in 1978 (EPA, unpublished data, 2000). On the basis of these figures, 14% of the VC remains as waste rock during commercial exfoliation. An exfoliation processing rate of 2,000 pounds of VC per hour would therefore generate approximately 280 pounds of waste rock per hour.

Many of the W.R. Grace exfoliation facilities manufactured a spray-applied fireproofing product sold commercially as Monokote®. The Monokote 3®, sometimes referred to as MK-3®, version of this product was formulated with VC and with 10% to 19% chrysotile asbestos as an additive. According to W.R. Grace records, chrysotile was received in bags that were opened manually and added to other ingredients in an industrial mixer during production of Monokote 3®

fireproofing product. The Monokote® mixer at many of these facilities had an exhaust stack to vent airborne dust and fibers from the mixing process to the outside air. W.R. Grace discontinued Monokote 3® production at all of the company's exfoliation facilities by July 5, 1973 (EPA, unpublished data, 2000).

Facility conditions during active vermiculite exfoliation often were described as dusty or very dusty. Anecdotal reports about past operations from former workers describe that "… every inch of the plant and offices was covered with dust" (ATSDR, unpublished data, 2006) and "…there was dust everywhere … it was so thick you could cut it with a knife" (Michigan Department of Community Health, unpublished data, 2005). One former worker relayed that the dust was visible on the clothes he worked in (and brought home for laundering) and that it coated the workers' cars parked outside of the plant (EPA, unpublished data, 2002).

Asbestos and dust control of both indoor and outdoor emissions at many of the W.R. Grace exfoliation facilities improved throughout the 1970s and 1980s in response to worker safety (OSHA) and environmental (EPA Clean Air Act) regulations [EPA 1990; OSHA 1994]. Outdoor asbestos emissions from these exfoliation facilities were not strictly regulated under 1970 EPA Clean Air Act amendments. However, W.R. Grace submitted information to EPA in May of 1973 indicating that 19 of the company's 31 exfoliation facilities had particulate and asbestos stack emission control equipment, including baghouse filters, that was compliant with the regulations (EPA, unpublished data, 2000). Information is not available to confirm compliance with the regulations or to evaluate directly the effectiveness of outdoor asbestos and dust emission control equipment at these facilities. Likewise, information is not available to follow up on facilities that were reported as not compliant in the 1973 memorandum to EPA.

As asbestos and dust control equipment were installed, a portion of the particulates that once were emitted into the air were captured instead by cyclones and baghouse filters. In some cases, state permits were required for outdoor stack emissions (typically furnace and mixer exhaust stacks) and for waste disposal of material collected by the dust control equipment. At an exfoliation facility in Weedsport, New York in 1970, stack test data for an exfoliation furnace without particulate control equipment indicated particulate emission rates of 6 pounds per hour during a production rate of 2,000 pounds of VC per hour (EPA, unpublished data, 2000). In 1986, W.R. Grace indicated in a state permit application that the particulates captured by the baghouse filter at the Santa Ana, California plant contained 1% to 3% asbestos, characterized as "friable tremolite" (EPA, unpublished data, 2000). A permit application submitted to Kentucky Air Pollution Control Commission in January, 1973, indicated that material collected in the baghouse filter for Monokote® mixer operations was approximately 20 pounds per hour during a maximum mixing rate of 3000 pounds of Monokote® fireproofing material per hour (EPA, unpublished data, 2000).

Records indicate that waste rock and fine particulates from the asbestos and dust control equipment at many of the W.R. Grace exfoliation facilities were bagged and disposed of at local landfills beginning in the early 1980s (EPA, unpublished data, 2000). Before 1980, very little information is available to track the handling and disposal of waste rock and fine particulates at these facilities.

The OSHA permissible exposure level (PEL) for occupational exposure to asbestos decreased from an initial standard of 12 f/cc promulgated in 1971 to the current standard of 0.1 f/cc established in 1994 [25]. In response, W.R. Grace initiated industrial hygiene monitoring,

including collection of personal samples and area samples, and various process design changes to achieve compliance at the company's exfoliation facilities (EPA, unpublished data, 2000). At some exfoliation facilities owned by W.R. Grace, the use of respiratory protection (e.g., dust masks, various types of respirators) was documented periodically for certain job categories in industrial hygiene reports dating back to the early 1970s (EPA, unpublished data, 2000). In 1977, W.R. Grace initiated an internal communication program intended to enforce respirator use and provide education to workers regarding the health effects of smoking combined with asbestos exposure (EPA, unpublished data, 2000). Information is not available to permit evaluation of the use or the effectiveness of this respiratory equipment in reducing worker exposures to asbestos. The overall effectiveness depends on several factors, including the protection factor of the masks, the effectiveness of the fit testing protocols, and the actual compliance of individuals required to properly wear the masks.

Findings for the 28 site evaluations

Tables 1 and 4 summarize various site characteristics that provide context for understanding potential exposures at each of the 28 sites. Additional information is provided in individual site profiles included in Appendix B.

Overall findings from the site evaluations are summarized in the following subsections, organized in terms of occupational, household contact, and community exposure pathways for past and for present and future scenarios. These findings apply primarily to the exfoliation sites studied (27 of the 28 sites).

Occupational exposure (past timeframe)

People who worked at the former exfoliation sites were exposed to hazardous levels of airborne asbestos during the time the facilities exfoliated VC from Libby. ATSDR aggregated personal and area sampling data received from W.R. Grace for 17 exfoliation sites during 1972–1992 (Appendix C). [17, 18] Measured PCM fiber levels inside the exfoliation facilities ranged from below detection levels to 139 f/cc. Before 1980, measured PCM fiber levels were typically in the range of 1 f/cc to 10 f/cc, which is above the current OSHA PEL of 0.1 f/cc for occupational exposure to asbestos (Figures 4 and 5; explanation of these data sets included in Appendix C). The OSHA PEL was 12 f/cc when it first was promulgated in 1971 [OSHA 1994]. It decreased over time to the current standard of 0.1 f/cc, established in 1994 [OSHA 1994].

The personal sampling data indicate a decrease in measured airborne fiber levels throughout the 1970s and 1980s (Figure 4). This trend is likely the result of a fiber reduction program implemented by W.R. Grace to achieve compliance with the OSHA asbestos standard promulgated in 1971 (EPA, unpublished data, 2000). Airborne fiber levels within these facilities before 1971 were probably in the same range or higher than the levels documented in the early 1970s (1 f/cc to 10 f/cc). Exposure to asbestos may have been higher than documented in Figure 4 for workers who manually performed some of the material handling processes, such as

[17] W.R. Grace may have initiated the industrial hygiene monitoring for asbestos in 1969 in conjunction with a dust control program described in company documents (EPA, unpublished data, 2000). However, ATSDR did not find any industrial hygiene sampling data for these facilities before the 1970s.

[18] This report analyzes the internal W.R. Grace occupational exposure data as reported, as it is often the only exposure data available with regard to the exfoliation sites. ATSDR cannot verify the accuracy of the data or the manner in which W.R. Grace conducted its occupational exposure sampling and analysis.

unloading VC from railcars, transferring VC into furnace hoppers, and transferring bulk quantities of waste rock.

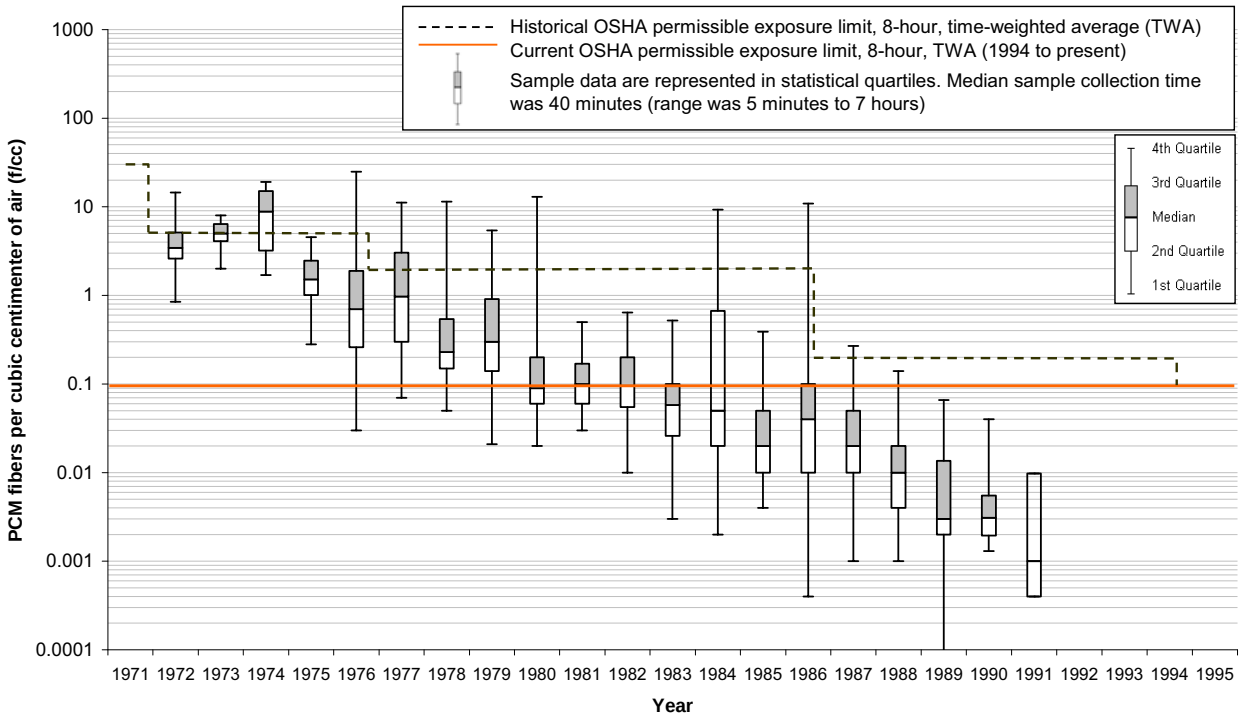

Figure 4. Airborne phase contrast microscopy (PCM) fiber concentrations over time: personal sample data (N=1,901) from 17 W.R. Grace vermiculite exfoliation facilities [Source: W.R. Grace industrial hygiene surveys, 1972–1991]

Area sampling data (Figure 5) indicate airborne fiber levels and trends similar to the personal sampling data. Most of the area sampling was conducted at locations in the exfoliation process where fibers were likely to be released (e.g., the furnace baghouse, the furnace stoner deck where waste rock and expanded product were separated, the waste rock hopper) (EPA, unpublished data, 2000). Some area samples were collected in common areas such as offices and employee lunchrooms. Airborne fiber results from the common areas were generally lower than in the active processing areas, but still of concern. For example, area samples collected in the late 1970s from employee lunch rooms at five different exfoliation facilities indicated fiber levels ranging from 0.08 to 3.0 f/cc.

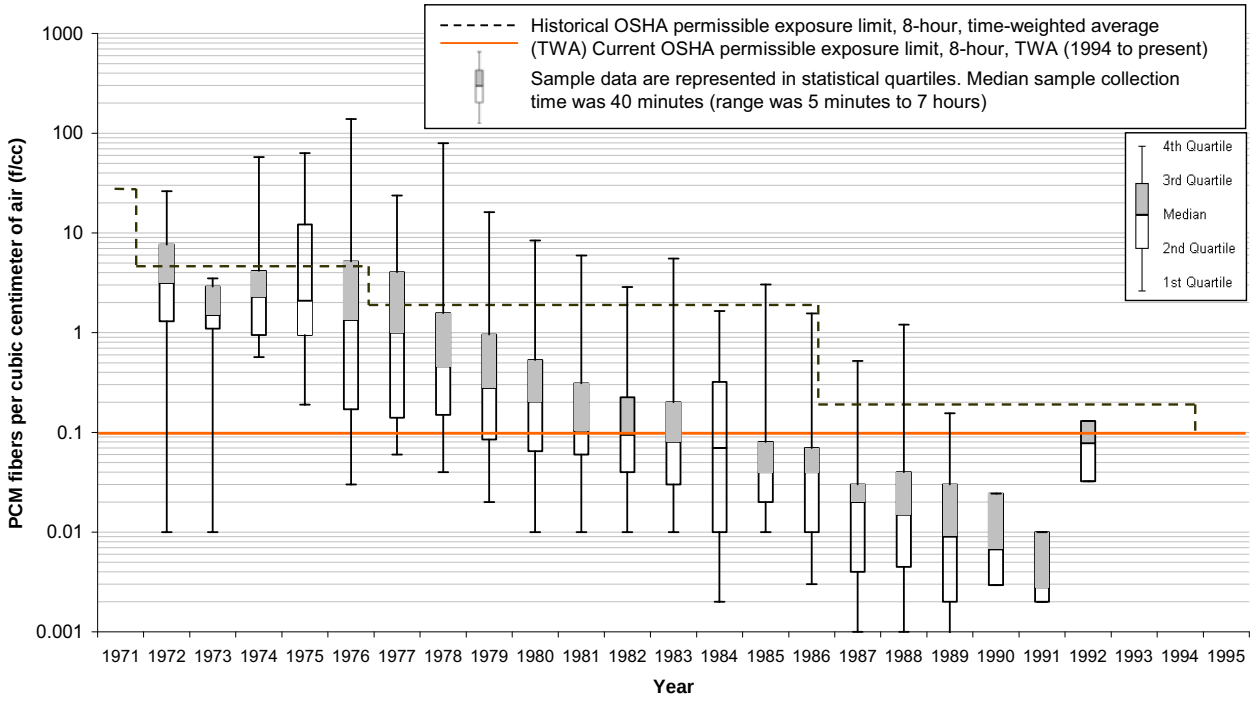

Figure 5. Airborne phase contrast microscopy (PCM) fiber concentrations over time: area sample data (N=902) from 17 W.R. Grace vermiculite exfoliation facilities [Source: W.R. Grace industrial hygiene surveys, 1972–1991]

The Monokote 3® fireproofing product manufactured at many of the W.R. Grace exfoliation facilities contained 10% to 19% chrysotile as an ingredient (EPA, unpublished data, 2000). Monokote 3® also contained vermiculite. Workers involved in mixing and packaging Monokote 3® may have been exposed to higher levels of airborne asbestos than workers who did not handle Monokote 3® because they handled both chrysotile and amphibole-containing vermiculite.

Fugitive emissions from loading, unloading, or transferring bulk VC or waste rock resulted in asbestos releases. Information provided to EPA in 1978 by a company that exfoliated VC from Libby indicated airborne PCM fiber levels were as high as 245 f/cc in an unloading area where VC was dumped from rail cars [EPA 1980]. In 1978, the Minnesota Department of Health (MDH) conducted personal monitoring on a worker who unloaded VC using a front-end loader at a non-W.R. Grace exfoliation facility in St. Paul, MN. Short-duration sampling results indicated airborne fiber levels of 3.9–23.3 f/cc, with a corresponding 8-hour time-weighted average calculated as 5.7 f/cc [MDH 1978].

Stack emissions from the exfoliation furnaces and the Monokote® product mixer contributed to outdoor fiber releases at these facilities. Both indoor and outdoor airborne fiber levels were probably higher before the 1970s. W.R. Grace installed particulate emission controls and initiated fiber reduction measures at many of its exfoliation facilities in the 1970s and 1980s in response to EPA and OSHA regulations. Little information was available about particulate and fiber controls at other, non-W.R. Grace exfoliation operations. Apparently, W.R. Grace provided engineering consulting services to the (non-W.R. Grace) exfoliation facility owner in St. Paul, MN in 1978. An internal W.R. Grace memorandum documents Grace's intention of suggesting dust and fiber control equipment (pick-up points) on the expanding furnace, stoner, and bagging hopper at the St. Paul plant (EPA, unpublished data, 2000). One can infer that there were no dust controls at these process points prior to the W.R. Grace consultation in 1978.

The process-related findings about vermiculite exfoliation operations provide insight into the frequency and duration of workers' exposure to asbestos at these sites. Most of the exfoliation facilities studied were dedicated to vermiculite exfoliation; such facilities operated one or more shifts for 5 to 7 days per week, transported and handled asbestos-containing vermiculite and waste material both inside and outside the facility, and often involved all employees working within one building structure. Given these documented conditions, it is likely that all employees at these facilities were exposed to asbestos. The actual magnitude, frequency, and duration of an employee's exposure would depend upon job assignment, period of employment, facility operation schedule, and facility practices (such as industrial hygiene controls and respiratory protection program).

Occupational exposure (present/future timeframe)

Current occupational exposure to asbestos at these sites is significantly lower than past occupational exposure. The Libby mine closed in 1990. Therefore, vermiculite exfoliation facilities stopped processing VC from Libby by the early 1990s[19], if not sooner. In the past, the primary source of exposure to former workers was active processing and handling of large quantities of VC, expanded vermiculite, and associated waste material. Former workers had frequent (e.g., daily) and direct contact with material that contained relatively high levels of asbestos. Now, the source of potential exposure at these sites is residual asbestos in soil and dust that, if present, are typically at low levels and in localized areas.

Current site conditions varied across the sites studied. Two of the sites have ongoing vermiculite exfoliation operations, several sites are awaiting redevelopment or sale, and most of the remaining sites are used for a variety of (non-exfoliation) industrial or commercial purposes (Table 4). In many cases, current operations are conducted in the same buildings that housed vermiculite exfoliation operations in the past.

The number and type of samples collected, the analytical methods used, and the sampling results obtained at these sites during recent (2000–2005) investigations varied. Despite the diversity of investigative approaches, EPA prescribed site cleanup, based on levels of asbestos detected, for more than half of the exfoliation sites that were sampled (Table 4). This held true for interior as well as exterior areas of the sites that were sampled. Interior sampling conducted at 20 exfoliation facilities resulted in detectable levels of asbestos that warranted clean-up actions at 11 of the former industrial facilities (55% of the sampled sites required cleanup). Exterior soil sampling conducted at 26 exfoliation facilities resulted in levels of asbestos that warranted 15 site clean-up actions (58% of the sampled sites required cleanup). The action level for cleanup of interior spaces varied. The action level for exterior cleanup was typically 1% asbestos in soil, although the clean-up and confirmation goals were often lower than 1%.

W.R. Grace reportedly cleaned the interior of its facilities with high-efficiency particulate air filter (HEPA) vacuums and wet cleaning methods when the company ceased vermiculite exfoliation operations in the past (EPA, unpublished data, 2000).[20] However, interior clean-up

[19] Records indicate that some facilities may have processed back stock from the mine or from their own storage areas for several years after the mine closed in 1990.

[20] This information came from an internal W.R. Grace policy document specifying clean-up procedures for plant shutdown. It is unclear how long this clean-up policy was in effect. Site-specific records of cleanup were generally not available for each site. Post-cleanup confirmation samples (typically 5 or 6 air samples) were available for some of the sites.

actions were necessary at several of these former W.R. Grace exfoliation facilities based on more recent (2000–2005), independent sampling results reported by EPA or the current site owner [ATSDR 2001a; ATSDR 2004; ATSDR 2005a].

The source of contamination in these indoor spaces was typically residual levels of asbestos detected in settled dust. At 2 sites, EPA, ATSDR, and state health department staff identified limited amounts of bulk source material (VC and waste rock) in indoor areas. Indoor cleanup at these sites was driven by the potential for current or future disturbances to create airborne asbestos levels of concern. Of note, at the 11 facilities where indoor cleanup occurred, available indoor air sampling results were below the current OSHA PEL of 0.1 f/cc.

Asbestos detected in outside soil typically was localized in areas where VC and waste rock were handled or stored, including railroad spurs where VC was unloaded, VC and waste rock stockpile areas, and storage silo areas. At many of the sites, VC and visible asbestos were observed in these areas during site visits conducted by ATSDR and state health department partners in 2002. Sampling results confirmed that these were areas of "worst case" surface soil contamination at the sites.

EPA investigations confirmed that waste material was buried at 3 of the former exfoliation sites in the past, with maximum levels of subsurface soil contamination as high as 12% to 18% asbestos [ATSDR 2004; ATSDR 2005a; ATSDR 2005b]. Quantities of contaminated soil excavated and removed from these sites during recent clean-up activities ranged from approximately 3,500 tons at the Dearborn, Michigan, site to 26,300 tons at the Wilder, Kentucky, site. ATSDR is working with EPA at a fourth exfoliation site (Ellwood City, PA) that may have waste rock buried on the site, according to anecdotal reports from community members and former workers and a review of historical aerial photographs of the site [ATSDR 2006a].

The two sites that have ongoing exfoliation operations use VC from vermiculite mines in South Carolina and South Africa. Reconnaissance studies conducted by USGS suggest that the fibrous amphibole content of domestic vermiculite deposits outside of Libby is low [USGS 2002]. Exposure studies conducted by NIOSH at 10 active facilities that either expand VC or use expanded vermiculite from mines in South Carolina, Virginia, and South Africa also suggest that the fibrous amphibole content of these mines is low and does not present a current exposure hazard to workers [NIOSH 2004]. Two of the 10 sites NIOSH investigated were also included in the ATSDR 28 site evaluations (Verlite Company, Tampa, Florida; The Scotts Company, LLC, Marysville, Ohio).

Household contact exposure (past timeframe)

Although exposure data are not available for household contacts, their exposure is inferred from documented former worker exposures and facility conditions that did not prevent contaminants from inadvertently being brought into the workers' homes. Exposure to asbestos resulting in asbestos-related disease in family members of asbestos industry workers has been well-documented [Peipins 2003; Anderson et al. 1979; Powell and Cohrssen 2001; Miller 2005]. Vermiculite exfoliation was reportedly a very dusty operation. The workers at these facilities did not wear uniforms (EPA, unpublished data, 2000). The W.R. Grace facilities did not have on-site laundering facilities (EPA, unpublished data, 2000). Some facilities had showers for employees, but anecdotal reports from former W.R. Grace employees indicate that the showers were not consistently used. Unless workers showered and changed clothes before going home, family

members or other household contacts likely were exposed to asbestos unintentionally brought home on the clothing, shoes, and hair of former workers. Household contacts also could have been exposed to asbestos from workers' personal vehicles that were parked outside the exfoliation facilities. These exposures cannot be quantified without information concerning the amount of asbestos on the workers' clothing and behavior-specific factors (e.g., worker practices, household laundering practices). This information may never be available.

Household contact exposure (present/future timeframe)

No data are available to permit evaluation of this pathway. However, household contact exposure to asbestos brought home on clothes, shoes, and hair of current or future workers would likely be minimal. Current workers are not actively processing and handling VC or waste material containing high levels of asbestos. Therefore, there is no reason to expect that significant quantities of asbestos are carried home on the workers' clothing.

Community exposure (past timeframe)

Community members who lived or worked near these sites in the past could have been exposed to asbestos from facility emissions, by disturbing or playing on VC or waste rock piles at the site, from direct contact with waste rock brought home for personal use, or from indoor household dust that contained asbestos from outside sources. Very little information is available to verify these types of community exposures or to quantify their magnitude, frequency, or duration. This information may never be available for many of the sites. ATSDR and state health partners confirmed significant community contact with waste rock at two sites, one in Minneapolis, MN and one in Ellwood City, PA.

When the facilities were operating, VC and waste rock may have been stockpiled temporarily on the site and accessible to children and other community members. MDH coordinated extensive community investigations and outreach around the former exfoliation facility in Minneapolis, Minnesota [MDH 2005]. During interviews of over 6,700 people associated with the facility and the surrounding neighborhood, 690 people reported that they played in or around waste rock piles at the exfoliation facility when they were children [MDH 2005]. In Ellwood City, Pennsylvania, people reported that as children they played at the "West End playground" located on the site [ATSDR 2006a]. Anecdotal reports suggest that 50 to 100 children gathered daily at the West End playground to play games (baseball, football) and use playground equipment (swings, seesaws, sandboxes). They played in and around the waste rock piles at the site and slid down the adjacent embankments where vermiculite waste reportedly was dumped when the plant was operating. They reported that the shiny vermiculite material covered the playground area.

At other sites, it appears that neighborhood children may not have had such widespread and frequent contact with VC or waste rock. ATSDR noted several reports of children playing on waste rock piles at the Dearborn, Michigan, site and in or near rail cars containing VC at the Hamilton, New Jersey, site [ATSDR 2004; ATSDR 2005c].

At the Minneapolis facility, waste rock was advertised as "free crushed rock," and many community members took it home to use in their yards, gardens, and driveways [ATSDR 2001a]. EPA inspected over 1,600 residential properties for the presence of asbestos. On the basis of sampling results, 260 residential yards in the community were remediated [EPA 2005b]. Anecdotal reports from community members prompted a similar investigative effort at the

Dearborn, MI, site. EPA contacted over 1,000 community members who live within ½ mile of the site, conducted visual inspections at 169 residential locations, and sampled 23 properties [EPA 2005c]. Asbestos was not detected in the residential yard samples [EPA 2005c].

The distribution of waste rock in the Minneapolis community seems to be a unique circumstance where a plant manager(s) actively promoted waste rock to the surrounding community. ATSDR could not find any information to indicate that this was a broader company policy suggested to or utilized by other facilities in the past. However, little information is available to determine whether or to what extent this happened at other exfoliation facilities, particularly before the 1980s when the waste rock began to be covered by disposal regulations. At a few sites, anecdotal reports from former workers indicated that they periodically took VC home for personal use.

People who lived or worked near these sites may have been exposed to airborne asbestos while the facilities were actively processing VC from Libby. Stack emissions from the exfoliation furnaces and the Monokote® product mixer resulted in asbestos releases into the air around these facilities. Fugitive emissions from loading, unloading, or transferring bulk VC or waste rock also contributed to outdoor asbestos releases. Dust and asbestos emissions were likely much higher before the 1970s, when particulate and asbestos control equipment was installed at many facilities.

MDH and the Minnesota Pollution Control Agency used site-specific facility and meteorological data to model past asbestos emissions for the former exfoliation site in Minneapolis, Minnesota [ATSDR 2003a]. Model results indicated a maximum long-term ambient air concentration of 0.0264 f/cc and a maximum short-term (1-hour) ambient air concentration of 0.868 f/cc around the site. Model simulations suggested that long-term airborne asbestos levels diminished rapidly to less than 0.01 f/cc within 1 to 2 blocks (approximately 50–60 yards) of the facility. These results represent a worst case scenario for facility emissions during 1936–1972, before stack emission controls were implemented.

Ambient asbestos levels in communities around other vermiculite exfoliation facilities would be highly dependent on source emission characteristics (stack height, emission rate), asbestos transport mechanisms, meteorological conditions, and topographic features around each facility. Exposure of people who lived or worked nearby would depend on human activity patterns (how long, how often a person spent time in an area with airborne asbestos). ATSDR does not have enough information to reliably quantify the exposures or the resultant risk of disease from airborne asbestos emissions from these facilities.

Community exposure (present/future timeframe)

Most community members who live or work near the 28 sites now are not being exposed to asbestos from the sites. The Libby mine closed in 1990. Therefore, vermiculite exfoliation facilities stopped processing VC from Libby by the early 1990s, if not sooner. The potential community exposure pathways of primary concern, from active facility emissions and from large, accessible stockpiles of VC or waste rock at the site generated during active processing, have been eliminated.

VC or waste rock brought home from these facilities in the past could still be a source of exposure to asbestos today, particularly when disturbed. If the asbestos is covered with soil,

grass, or other vegetation and it is not disturbed, fibers will not become airborne and will not pose a public health hazard.

Asbestos could be present in homes near these sites from past transport mechanisms, such as airborne transport of fibers from facility emissions or fibers brought home on workers' clothing and hair. Routine housekeeping over the years would have removed or reduced greatly any residual asbestos in indoor areas.

In some cases, community members could be exposed to residual asbestos at a site if they visit a site for legitimate business (as customers or tenants), trespass on a site, or occupy a site after redevelopment (assuming redevelopment does not include assessment and cleanup of residual asbestos as needed).

Each of the potential exposure scenarios described above likely would result in low-level, intermittent exposure to asbestos. As mentioned previously in this report, little scientific information is available about the health risks associated with this type of exposure.

Information about non-exfoliation sites

During the 28 site evaluations, ATSDR collected incidental information about non-exfoliation sites that received VC from Libby. This information—derived from W.R. Grace documents (EPA, unpublished data, 2000), EPA regional records, and state health department investigations—was predominantly about gypsum wallboard manufacturing plants that received VC from Libby. The Environmental Health Investigations Branch and the Occupational Health Branch of the California Department of Health Services contributed valuable information from their site investigations at two California gypsum board facilities that processed vermiculite from Libby in the past [CDHS 2004; ATSDR 2006b]. Little or no data were available readily for other non-exfoliation industries that received and used VC from Libby. EPA conducted preliminary and/or detailed site assessments during 2000–2002 at many of the sites it identified as having received VC from the Libby mine. Non-exfoliation sites were included in these investigations. According to EPA summary reports, none of the non-exfoliation sites required cleanup based on the presence of residual asbestos (EPA, unpublished data, 2002 and 2003).

Gypsum wallboard manufacturing plants were the largest user group among the non-exfoliation sites, with 52 different sites that collectively received approximately 3% of the known VC shipments from Libby.[21] To make gypsum board (also known as drywall or sheetrock), the mineral gypsum is blended with other dry additives such as VC, and water is added to form a slurry. The gypsum slurry is placed between two layers of paper and this assembly is then dried and cut into panels of standard size [EPA 2006b]. Some of the factors that are important in considering exposure to asbestos-containing VC during this process include the following.

- VC was added to wallboard products in relatively small quantities. Finished wallboard products contained less than 1% VC by weight [CDHS 2004]. VC contained 0.3% to 7% asbestos [Addison and Davies 1990]. Therefore, the amount of asbestos in the finished wallboard is estimated to be less than one percent of 0.3% to 7%, or less than 0.003% to 0.07%.

[21] According to the shipping invoice data referenced in the background section of this report, the 152 non-exfoliation sites on EPA's list of 245 sites received less than 5% of the VC shipped from Libby during 1964–early 1990s.

- VC was only used in the formulation of the more fire-resistant types of wallboard. When exposed to high heat, the gypsum component of the wallboard shrinks as the associated water molecules absorb heat and vaporize. The (unexpanded) VC additive expands under high heat and absorbs heat in the process. This offsets the shrinkage of other components and provides for longer structural stability of the wallboard [Bucholtz 2006; Georgia-Pacific 2006].
- In many cases, VC was delivered to gypsum wallboard manufacturing facilities in bags instead of in bulk (EPA, unpublished information, 2000–2001).[22] Moving and handling VC in bags instead of in bulk likely would have minimized asbestos emissions in and around the facility. Asbestos would have been released into the air primarily when the bags of VC were opened for use or when bags were broken or spilled during handling.
- In the past, workers were exposed to asbestos when they manually opened the bags of VC and poured them into a hopper for blending with gypsum and other dry additives [CDHS 2004]. In downstream processing, the VC and associated asbestos were entrained in the wet slurry or encased in the gypsum core sandwiched between layers of paper. Some asbestos could have been released into the air when the boards were cut and sized. However, the small surface area of the edge cuts and the low amount of asbestos in the finished product would likely result in minimal asbestos releases into the plant air.

Exposure to asbestos at these gypsum wallboard manufacturing facilities likely was limited to workers who had direct contact with the VC (opening and pouring bags of VC into the process equipment) and workers who cleaned and maintained the hopper, mixer, ventilation, or other equipment or specific areas associated with the VC additive. Due to the low volumes of VC handled and the containment of VC throughout much of the manufacturing process (in bags, entrained in wet slurry, encased in gypsum wallboard core), asbestos contamination was likely not widespread throughout the facilities or the surrounding sites.

As stated previously, little or no data were collected for non-exfoliation industries other than gypsum wallboard manufacturing. Using the shipping invoice summary data from EPA, ATSDR estimates that the 93 sites in this category (from EPA's list of 245 total sites) received 2% of the VC shipped from Libby during 1964–early 1990s. Most of these non-exfoliation sites used relatively small quantities of VC from Libby. If they primarily received VC in bags rather than in bulk via rail car, much of the fugitive emissions and airborne fiber levels associated with material transfer and handling would have been reduced or eliminated. Because the non-exfoliation sites received very low amounts of VC from Libby, historical exposure to asbestos likely was confined to workers who had direct contact with the VC. Residual contamination at these non-exfoliation sites is expected to be minimal.

Discussion

The findings from the 28 site investigations are applicable to all exfoliation facilities that processed VC from Libby. Much of the information about exfoliation operations came from internal W.R. Grace documents. However, non-W.R. Grace facilities that exfoliated VC are

[22] ATSDR reviewed information submitted to EPA Region 9 by seven gypsum board companies that received VC from Libby in the past. Six of the seven facilities received VC in bags; the seventh gypsum board facility received VC in bulk via railcar. The latter facility also exfoliated VC at the site.

expected to be very similar. Some of the independently-owned facilities were licensees of W.R. Grace and received guidance from W.R. Grace on product formulations and operating procedures (EPA, unpublished information).

Past exposure to asbestos at former exfoliation facilities

The 28 site evaluations highlight three groups of people who experienced the most significant exposure to asbestos associated with sites that exfoliated VC from Libby: former employees at exfoliation facilities, household contacts of these former employees, and some community members—particularly children—who had frequent, direct contact with VC or waste rock from exfoliation facilities in the past.

The total number of former workers and household contacts affected at each site depends on several variables, including the number of employees at the facility, the turnover rate for employees, and the number of years the facility operated. Available information indicates that the number of exposed former workers and household contacts at former vermiculite exfoliation sites could range from 350 to 700 people per site.

Aside from smoking cessation and reducing future exposure, there are no known post-exposure prevention measures. Treatment options for persons who have already developed asbestos-related disease are limited. Nevertheless, public health agencies can promote awareness of past exposure and encourage healthy choices that may reduce the risk of developing asbestos-related disease. Appropriate health guidance for persons exposed to asbestos includes smoking cessation, informing personal or primary care physicians of past exposure, reducing future exposure to asbestos, and obtaining appropriate influenza and pneumonia vaccinations.

Many challenges are associated with notifying exposed persons associated with these sites. Because these exfoliation facilities operated in the past (some more than 40 or 50 years ago), former employee names and current contact information may not be available. People who worked at these sites decades ago may have lived in adjoining communities, or they may have moved away from the area. Tracing and locating these people cannot be accomplished without names and some form of unique personal identifiers such as past addresses or social security numbers.

Health care providers who are on the front lines of collecting exposure histories or diagnosing and referring patients should be informed about nontraditional asbestos-related occupations (such as vermiculite exfoliation employees) and non-occupational exposure associated with asbestos-containing VC. They also should be cognizant that asbestos-related diseases typically have a latency of 15 to 40 years after initial exposure to asbestos. Promoting awareness among local health care providers within the health care systems surrounding communities where former exfoliation sites were located may be useful, given the challenges of direct notification of persons who may have been exposed to asbestos. Informing health care providers about asbestos-containing VC exposure and health issues through professional organizations, trade journals, conferences, and similar channels should be an ongoing public health goal. Information about asbestos-containing VC should be integrated into the existing body of asbestos-related material published for medical professionals.

Information concerning asbestos-containing VC has been incorporated into the general asbestos knowledge base provided via the Internet by many federal agencies, including ATSDR, EPA,

and NIOSH. Efforts to include asbestos-containing vermiculite in informational materials and guidance about asbestos for public health and environmental regulatory professionals, environmental consultants and remediation workers that specialize in asbestos issues, and analytical laboratories that are certified in asbestos analyses should continue.

Current and future exposure to asbestos at former exfoliation facilities

Remediation is a definitive solution for eliminating potential exposure to residual asbestos at these sites. However, health-based action levels and endpoints for asbestos cleanup, particularly for contamination present in soil and dust, are not defined clearly or universally in regulations or in available risk assessments. Adopting artificially low standards for cleanup would introduce undue financial burdens at many sites and practical complications in geographic regions where background levels of asbestos are elevated naturally (areas of California, for example). Ideally, clean-up standards for eliminating or reducing exposure to asbestos should be based on risk assessment methods that are relevant to Libby amphiboles and should incorporate site-specific exposure factors, including land and building use and human activity patterns involving contaminated soil and dust.

EPA currently is involved in several research efforts that will facilitate setting health-based clean-up levels in Libby, MT [Bodine 2007; EPA 2007a; EPA 2007b]. These efforts include comparative toxicity testing, improved analytical techniques for environmental samples, and methods for addressing exposure due to re-suspension of asbestos from soil to air. NIOSH also recently proposed projects to improve sampling and analytical methods for asbestos, to develop information on occupational exposures to asbestos and health outcomes, and to develop a broader understanding of the important determinants of toxicity for fibers and fiber-like cleavage fragments [NIOSH 2008]. The results of these efforts, which are several years from completion, will be extremely useful in the future for evaluation and remediation (if necessary) of asbestos-containing sites. In a recent report, GAO recommends additional work at sites that received vermiculite from Libby, including determination of "… (1) the manner and extent to which newly available sampling and analysis techniques should be used to re-evaluate the threat that the sites receiving Libby ore may pose to human health, and (2) whether any additional sites that received the Libby ore need to be cleaned up when the results of the [Libby] risk and toxicity assessment—now scheduled to be completed in 2010—are available" [GAO 2007].

Information from the 27 exfoliation sites ATSDR studied suggests that residual levels of asbestos are present in indoor settled dust and outdoor soil at many former exfoliation sites that processed VC from Libby. Current employees at these sites may be exposed to residual asbestos, but potential exposures are substantially less than former occupational exposure during active processing and handling of large quantities of VC and associated waste material.

For some of the former exfoliation sites, environmental sampling data are not available to characterize potential residual contamination in indoor or outdoor areas where VC and waste rock were commonly handled. Data gaps also exist for historical (pre-1980s) handling and disposal of waste rock at these facilities. EPA confirmed that waste rock was buried at three of the exfoliation sites in the past. Buried waste material may not be present at all of these sites; the small size of many of the sites would have precluded this as a disposal option. Asbestos-containing material does not present a hazard as long as it is buried. However, it could present a hazard during future site development or excavation activities.

The potential health significance of current exposure to residual asbestos at some of these sites is difficult to evaluate. Much of the available sampling data consist of measured asbestos levels in settled dust, soil, or other bulk material. These measurements are not representative of potential airborne exposure from disturbing materials contaminated with Libby amphiboles. Potential current exposure to residual levels of asbestos at these sites is considered low-level, intermittent exposure, and little scientific information is available about the health risks associated with these types of exposure. Recent projects initiated by EPA, NIOSH, and ATSDR will contribute valuable scientific information that can be used to make health-based cleanup decisions at asbestos-contaminated sites (EPA 2007a, EPA 2007b, NIOSH 2008, ATSDR 2008).

The general population is exposed to low levels of asbestos in outdoor air ranging from 10^{-8} to 10^{-4} f/cc (Table 3) [ATSDR 2001]. As a result, any incremental difference in health risk that may exist between background exposure and some additional low-level, intermittent exposure to asbestos is difficult to measure. Background levels of airborne asbestos result from natural processes that weather asbestos minerals in the environment and from normal wear and deterioration of a myriad of commercial products that contain asbestos, including automobile brake and clutch materials, floor tiles, thermal system insulation such as pipe and boiler coverings, and structural fire-proofing materials, among others.

For most of these sites, the occupational setting is the likely pathway for exposure to residual asbestos that may remain at the site. Site owners, employees, or others concerned about residual asbestos in the form of Libby amphiboles at a site could request assistance through federal and state OSHA offices that have established mechanisms for conducting work site evaluations and consultations. NIOSH may also be a source of assistance at active work sites through its Health Hazard Evaluation program.

On a practical note, the current OSHA occupational standard of 0.1 f/cc (8-hour TWA) for asbestos may not be protective enough for Libby amphiboles. When analyzed under IMA/Leake classification criteria, Libby amphiboles are classified as being composed primarily of winchite and richterite, which are not included in the definition of asbestos provided within OSHA regulations. In work environments where asbestos typically is handled, OSHA still recommends work practices such as engineering controls and respiratory protection to reduce occupational exposure to asbestos because OSHA acknowledges that an unacceptable level of health risk remains when the 0.1 f/cc PEL is used [OSHA 1994]. Additionally, OSHA regulations regarding air monitoring for asbestos exposure may not be strictly applicable in an occupational setting where asbestos is a residual contaminant from past operations rather than a component or ingredient of the current work flow.

Unique considerations for sampling, analyzing, and assessing exposure and health risk are associated with the Libby amphiboles. Ongoing and future assessments at sites that involve Libby amphiboles would benefit from a consistent investigative and decision-making framework that utilizes the most appropriate tools available for measuring and evaluating amphiboles. EPA and NIOSH have begun new studies, the results of which will be extremely useful in the future for evaluation and remediation (if necessary) of asbestos-contaminated sites. In the meantime, EPA has technical resources available to guide site assessment activities, including the Technical Review Workgroup (TRW) Asbestos Committee. The TRW is an EPA workgroup convened "… to support and promote consistent application of the best science in the field of risk assessment for metals and asbestos at contaminated sites nationwide"

(http://www.epa.gov/superfund/health/contaminants/lead/trw.htm). Senior scientists from ATSDR are part of the TRW Asbestos Committee, and ATSDR is committed to providing technical support on asbestos issues through this collaboration. The TRW Asbestos Committee developed a guidance document, entitled the "TRW Framework for Investigating Asbestos-Contaminated Superfund Sites," which is currently undergoing external peer review.

Non-exfoliation sites

On the basis of available information, additional comprehensive investigative or health follow-up activities beyond the evaluations already undertaken at these non-exfoliation sites do not seem warranted. Non-exfoliation facilities, which account for 145 of the 245 sites on EPA's list, received less than 5% of the VC shipped from Libby during 1964–early 1990s. Available information suggests that many of these facilities received relatively small quantities of VC; VC shipments were made in bags rather than in bulk via rail cars, and processing methods relied on using the VC as is instead of expanding or "popping" it as was done in exfoliation. These factors indicate that exposure to asbestos at non-exfoliation sites was likely limited to workers who had direct contact with the VC and would likely be much lower in magnitude and duration than the exposures documented at exfoliation sites. Additionally, asbestos contamination likely was not widespread throughout the facilities. The potential for significant residual contamination at these sites likewise would be low.

EPA evaluated many of these non-exfoliation sites in 2000–2002, during preliminary site assessments for sites that received VC from Libby. According to EPA summary reports, none of the non-exfoliation sites required cleanup based on the presence of residual Libby amphiboles (EPA, unpublished data, 2002 and 2003).

ATSDR and state health departments are examining existing health statistics for communities surrounding some of these non-exfoliation sites as part of a larger effort that encompasses 69 sites in 23 different states. Findings from this effort are summarized in a separate report [Horton et al. 2008].

Limitations

The tonnage figures attributed to each of the 28 sites (Table 1) are rough estimates at best. The W.R. Grace shipping invoice database, available for 1964–early 1990s, covers the peak production period of VC in the United States (Figure 6). However, the total tonnage of VC received by facilities that operated during the 1920s–1963 is underestimated by the database because invoices were not available before 1964. The database of available shipping invoices contains duplicate records, incomplete records, billing addresses (vs. actual processing facility addresses), and other imperfections. ATSDR compared cumulative records from the invoice database to a limited number of available W.R. Grace internal annual reports (obtained directly from the EPA database of W.R. Grace documents) and noted that the invoice database appeared to overestimate the tonnage received by individual facilities by an estimated 10% to 110%.

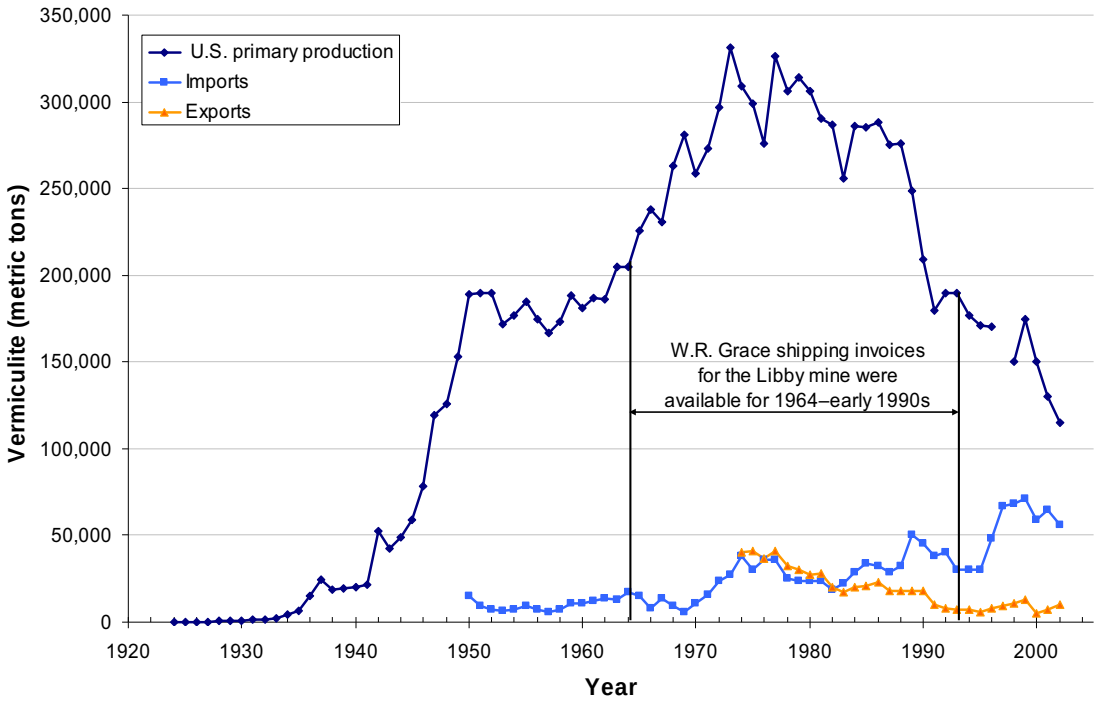

Figure 6. Historical vermiculite statistics from the U.S. Geological Survey, February 2004. Data and notes on data sources are available at Hhttp://minerals.usgs.gov/ds/2005/140/H.

Exposure data, including magnitude, frequency, and duration of exposure, are not available for many of the past and current exposure pathways. This information may never be available, particularly for past exposure scenarios.

The industrial hygiene information ATSDR reviewed was post-1970, when W.R Grace began monitoring worker exposure and process emissions in response to environmental and worker safety regulations. W.R. Grace also started implementing asbestos and dust control measures at its facilities in response to these regulations. Airborne asbestos levels generated from processing and handling VC and waste rock at these facilities would have been higher before these control measures were implemented.

While some exposure data and facility operating information were available for W.R. Grace facilities, much less is known about independent exfoliation facilities that were not owned by W.R. Grace. Some of these facilities may have been slower (than W.R. Grace) in implementing dust and fiber control measures in response to environmental and worker safety regulations promulgated in the 1970s (EPA, unpublished data, 2000). The available airborne asbestos levels summarized in Figures 4 and 5 (also Figures C-1 and C-2 in Appendix C) for the period of 1972–1992 likely underestimate actual conditions at the independently-owned exfoliation facilities. However, it is important to note that ATSDR cannot verify the accuracy of the available exposure data or the manner in which W.R. Grace conducted its occupational exposure sampling and analysis.

There are unique considerations for analyzing Libby amphiboles in environmental samples. Many different methods are used to analyze for asbestos, but not all of them provide the kind of information needed to make health-related decisions. The limitations inherent in many of the

analytical methods and reporting protocols may result in underestimation or overestimation of the toxicologically relevant asbestos in an environmental sample.

Personal and area air samples collected during industrial hygiene studies in the past typically were analyzed by PCM. PCM techniques alone cannot distinguish between asbestos and nonasbestos fibers. PCM techniques also cannot detect very thin fibers (fibers that have diameters less than 0.25 μm). These limitations could result in measured fiber levels that overestimated or underestimated the actual concentration of asbestos in the samples. Nevertheless, because established occupational exposure limits are based on PCM measurements, the PCM results collected in the past at these facilities provide an index of the fiber exposure (which is not the same as an actual fiber concentration).

Although the recent (2000–2005) environmental data for these sites are not presented in detail in this report, ATSDR observed several limitations in these data during the site evaluations.

- Most of the available site-specific sampling results do not definitively describe the mineralogy and fiber size distribution of the asbestos detected.
- Most of the analytical methods used are limited in their ability to distinguish between different amphibole types. Therefore, it was often unclear if the predominant Libby amphiboles (winchite and richterite) were included or excluded from reported results.
- The counting rules used for asbestos analysis may have underestimated or overestimated actual asbestos concentrations, depending on what fiber lengths and aspect ratios were counted and how groups of fibers and non-asbestiform particles were defined and counted.
- Light microscopic techniques, including PCM and PLM, cannot detect fibers that are thinner than 0.25 μm; therefore, these methods would underestimate asbestos concentration for samples with thin fibers.
- PCM techniques alone cannot distinguish between asbestos and nonasbestos fibers. In current industrial or commercial environments that generate nonasbestos fibers, PCM analysis may overestimate actual asbestos concentrations

These analytical uncertainties are perhaps more important for environmental exposures where less is known about the types of fibers that might be found (as compared to an industrial environment where well-characterized materials are present). The uncertainties are less significant in settings where site-specific information can help fill in the analytical data gaps. Most of the former exfoliation facilities, for example, were dedicated to vermiculite processing, where the contaminant is known to be Libby amphiboles.[23] In this setting, asbestos exposure levels were orders of magnitude higher than the current OSHA PEL, and the exposure to workers was chronic. Therefore quantifying the exact mineralogy and size of these fibers is not as critical for health-based decision-making. Still, it must be acknowledged that not enough information is available to characterize fully the exposure setting and the population of Libby amphiboles in environmental media at these sites, particularly from a historical dose reconstruction perspective.

[23] Chrysotile fibers were also a known contaminant at exfoliation facilities that produced Monokote 3® before 1973.

Conclusions and recommendations

The conclusions and recommendations presented in this report are intended as a general framework for follow-up activities. They may be implemented by many different entities, including site owners and local, state, and federal agencies. The number and variety of sites, stakeholders, public health and regulatory organizations, and jurisdictions involved suggest that a cooperative and flexible approach is necessary to effectively identify and implement follow-up actions appropriate for individual sites.

ATSDR acts in an advisory, nonregulatory capacity, working with communities, environmental groups, and local, state, and other federal groups to protect public health. ATSDR's role in supporting the recommendations in this report will vary from providing technical assistance to participating in implementation. Senior ATSDR scientists are part of EPA's TRW Asbestos Committee, and ATSDR is committed to providing technical support on asbestos issues through this collaborative effort. Additionally, ATSDR continues to support many activities to understand better the potential public health effects at sites that processed asbestos-containing vermiculite. Some of these activities include worker studies, community surveys and screenings, and disease-specific surveillance. These projects are progressing independently and their findings will be published in separate reports in the future.

Conclusion (1)

On the basis of the 28 site investigations, ATSDR identified these three groups of people who experienced significant exposure to asbestos (specifically Libby amphiboles) associated with vermiculite exfoliation facilities:

- Former employees,
- Household contacts of former employees, and
- Some community members, particularly children, who had frequent, direct contact with VC or waste rock from these facilities.

These groups were exposed to asbestos in the past, when the facilities actively were exfoliating VC from Libby. They likely have increased risk for developing both carcinogenic and non-carcinogenic asbestos-related diseases. Actual health risks for individuals would vary according to a number of factors, including frequency, duration, and intensity of exposure (to asbestos), size and type of asbestos to which one was exposed, personal risk factors (smoking, history of lung disease, and genetic susceptibility), age at initial exposure, and use and effectiveness of personal protective equipment (for workers).

Recommendation for conclusion (1)

Increase awareness about exposure to asbestos associated with past vermiculite exfoliation operations among (1) people who experienced significant exposure to asbestos associated with exfoliation facilities, (2) health care providers, and (3) public health and environmental professionals. Suggested activities:

- ATSDR and state health departments should continue to provide health education materials to individuals who self-identify as having been exposed to asbestos associated with vermiculite

exfoliation. The many challenges to identifying and locating exposed persons may limit active outreach efforts. Exposed persons should be encouraged to discuss their exposure with their health care providers.

- Consider the efficacy of localized outreach strategies for communities surrounding former exfoliation sites to create opportunities for self-identification among former workers and other exposed groups. Such an effort may not be justified for communities where significant demographic changes occurred after the local vermiculite exfoliation facility closed.
- Promote available ATSDR self-instructional publications, including *Case Studies in Environmental Medicine: Asbestos Toxicity* and *ATSDR Environmental Medicine Grand Rounds: Asbestos Toxicity*[24], as tools for informing pulmonologists and other health care providers about occupational and non-occupational exposure to asbestos associated with past vermiculite exfoliation operations.
- Integrate information about asbestos-containing VC into existing guidance for asbestos-related health care and into existing occupational, medical, and environmental literature, book chapters, conferences, peer reviewed journals, and other publications.

Conclusion (2)

The findings from evaluations of 27 exfoliation facilities (most of which operated in the past) suggest that residual asbestos in the form of Libby amphiboles may be present in ***indoor settled dust*** at many of the other 78 sites identified as former exfoliation facilities. Many of these facilities currently are being used for other, non-exfoliation commercial or industrial operations.

EPA site assessment and sampling data from 2000–2005 for interior areas at 27 exfoliation sites indicate:

- Sampling data were available for 20 of the 27 exfoliation sites.
- Sampling results prompted interior cleanup at 11 sites.
- Sampling data were not available for indoor areas at 7 sites.
- The number and type of samples collected, the analytical methods, and the decision-making framework used to evaluate indoor areas varied.
- The primary source of potential exposure in indoor spaces was residual asbestos in settled dust.

Note that because these 27 sites were not selected randomly from the group of known former exfoliation sites, they may have been more likely to have residual Libby amphiboles in indoor settled dust.

[24] Both items are available at www.atsdr.cdc.gov/csem/asbestos/cover2.html.

Conclusion (3)

The findings from evaluations of 27 exfoliation facilities (most of which operated in the past) suggest that residual asbestos in the form of Libby amphiboles may be present in ***exterior soil*** at many of the other 78 sites identified as former exfoliation facilities. Many of these facilities currently are being used for other, non-exfoliation commercial or industrial operations.

EPA site assessment and sampling data from 2000–2005 for exterior areas at 27 exfoliation sites indicate:

- Sampling data were available for 26 of the 27 exfoliation sites.
- Sampling results prompted exterior cleanup at 15 sites.
- Sampling data were not available for exterior areas at 1 site.
- The number and type of samples collected, the analytical methods, and the decision-making framework used to evaluate exterior areas varied.
- Residual asbestos was typically found in areas where VC and waste rock were handled or stored, including rail spurs where VC was unloaded, stockpile areas, and storage silo areas.
- Waste rock was buried at three former exfoliation sites; investigations are continuing at a fourth exfoliation site where waste material was reportedly buried. Asbestos-containing material does not present a hazard as long as it is buried. However, it could become a source of exposure during future site development or excavation activities.

Note that because these 27 sites were not selected randomly from the group of known former exfoliation sites, they may have been more likely to have residual Libby amphiboles in exterior soil.

Recommendations for conclusions (2) and (3)

Evaluate existing site information and sampling data for all exfoliation facilities, using a consistent investigative and decision-making framework to identify and eliminate or reduce current exposures to asbestos that pose an unacceptable risk. Action levels and clean-up standards should be relevant to Libby amphiboles and should incorporate site-specific factors, including current land and building uses.

- Review existing site inspection and sampling data for all exfoliation sites, using a consistent investigative and decision-making framework; refer to guidance from EPA's Technical Review Workgroup (TRW) Asbestos Committee.
- Ensure that visual inspection and environmental sampling data are adequate to assess the following material handling areas in particular: rail spur areas where VC was unloaded, indoor building spaces where exfoliation occurred, VC and waste rock storage areas, and areas where waste rock may have been buried or placed.
- Collect additional environmental samples at these sites as needed to identify current exposures to residual asbestos in the form of Libby amphibole contamination.

- Eliminate or reduce current exposures to asbestos that pose an unacceptable risk.

Conclusion (4)

ATSDR did not conduct a detailed review of non-exfoliation sites. These factors suggest that follow-up activities at non-exfoliation sites may not be warranted, or should be a lower priority than those at exfoliation sites:

- Overall, non-exfoliation sites received less than 5% of the VC shipped from Libby during 1964 until the early 1990s.
- ATSDR gathered incidental information indicating that many of these facilities received relatively small quantities of VC, the VC shipped in closed bags rather than in bulk via rail cars, and processing methods used the VC in the condition in which it arrived, instead of expanding it, as was done in exfoliation.
- According to EPA summary reports, none of the non-exfoliation sites visited by EPA during 2000–2002 required cleanup based on the presence of residual Libby amphiboles.

Recommendation for conclusion (4)

Non-exfoliation sites should not be broadly targeted for follow-up activities. However, some of these sites may require further review or investigation on a case-by-case basis.

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Tables

Table 1. Agency for Toxic Substances and Disease Registry (ATSDR) list of 28 sites

ATSDR/ EPA Region	Facility name during vermiculite processing operations	City	State	Site selection criteria*	Estimated timeframe for processing vermiculite concentrate from Libby†	Timeframe from invoices‡	Tonnage from invoices‡
1	Zonolite Company/W.R. Grace & Company (WRG)	Easthampton	MA	EPA/tonnage	1963–1984	2/66–9/84	183,300
2	Celotex	Edgewater	NJ	EPA	1967–1969	10/67–10/69	300
2	Zonolite Company/WRG	Hamilton Township	NJ	EPA/tonnage	1948–early 1990s	1/66–12/88	204,821
2	Zonolite Company/WRG	Weedsport	NY	EPA/tonnage	1963–1989	1/66–12/91	114,467
3	Zonolite Company/WRG	Beltsville	MD	EPA	1966–early 1990s	1/66–11/88	93,100
3	Zonolite Company/WRG	Ellwood City	PA	EPA	1954–1969	1/66–6/69	9,500
3	WRG	New Castle	PA	EPA/tonnage	1969–1992	6/69–11/88	172,100
4	Zonolite Company/WRG	Tampa	FL	tonnage	1950s–1991	2/66–1/91	112,100
4	Zonolite Company/WRG	Wilder	KY	EPA/tonnage	1952–1992	7/53–12/88	222,100
5	WRG	West Chicago	IL	tonnage	1974–early 1990s	2/74–12/88	273,600
5	Zonolite Company/WRG	Dearborn	MI	EPA/tonnage	early 1950s–1989	1/66–11/88	206,100
5	Western Mineral Products Company	Minneapolis	MN	EPA/tonnage	1936-1989	1/51–9/88	122,800
5	O.M. Scott & Sons	Marysville	OH	tonnage	1963–1980	1/67–11/80	429,500
6	Zonolite Company/WRG	New Orleans	LA	tonnage	1965–1989	6/66–12/88	148,300
6	Texas Vermiculite Company/WRG	Dallas	TX	tonnage	1953–1992	1/67–3/93	396,900
7	Zonolite Company/WRG	St Louis	MO	tonnage	1944–1988	1/66–9/88	139,500
7	Western Mineral Products Company	Omaha	NE	tonnage	1940s–1989	1/67–1/91	166,500
8	Western Mineral Products Company	Denver	CO	EPA/tonnage	1950–1990	1/67–11/88	103,000
8	Robinson Insulation Company	Minot	ND	EPA	1945–1983	2/67–6/83	16,200
9	Ari-Zonolite Company.	Glendale	AZ	EPA	1951–1964	Unknown	Unknown
9	WRG	Phoenix	AZ	EPA/tonnage	1964–1992	5/69–10/92	254,900
9	California Zonolite/WRG	Glendale (L.A.)	CA	EPA/tonnage	1950–1977	1/67–7/79	120,200
9	WRG	Newark	CA	EPA/tonnage	1966–1993	1/67–2/92	337,100
9	WRG	Santa Ana	CA	EPA/tonnage	1971–1993	12/71–8/88	453,000
9	Vermiculite of Hawaii	Honolulu	HI	EPA	1954–1983	1/67–8/83	6,000
10	Vermiculite Northwest, Inc./WRG (Harding Avenue)	Portland	OR	EPA/tonnage	early 1950s–1993	1/67–10/91	198,500
10	Supreme Perlite Company (Suttle Road)	Portland	OR	EPA	1968–1974	12/71–4/74	700
10	Vermiculite Northwest, Inc./WRG	Spokane	WA	EPA	1940s–1974	1/66–2/74	15,200

Notes: All of the sites listed are former or current exfoliation facilities, except for the Edgewater, NJ site, which is a former gypsum board manufacturing facility.
Gray shading indicates sites for which ATSDR was the lead public health agency (14 sites). State health departments led the site evaluations for the unshaded sites (14 sites).

* Site selection criteria: EPA = Site was listed as a further action site by the US Environmental Protection Agency (EPA) based on current site conditions (EPA site list dated September 25, 2002)
tonnage = Site was listed as an exfoliation facility that processed > 100,000 tons of Libby vermiculite concentrate (EPA, unpublished data, 2001)

† Best estimate for timeframe that the facility handled or processed vermiculite concentrate from Libby, Montana, based on invoice data and site-specific information.

‡ Information (timeframe and vermiculite concentrate tonnage) from EPA's database of WRG invoices (approximately 1964-1990s). This database may underestimate or overestimate the actual tonnage of vermiculite concentrate received by a facility (see Limitations section of this report). Tonnage estimates are rounded to the nearest 100 tons.

Table 2. Potential pathways of exposure to asbestos at sites that processed vermiculite concentrate from Libby, Montana

Source of asbestos	Release and transport* mechanisms	Exposure medium	Point of exposure	Route of exposure	Receptor population (Timeframe)
Vermiculite concentrate and waste material	• Unloading, loading, transferring large quantities of vermiculite concentrate and waste material • Exfoliation ("popping") of vermiculite concentrate (typically at a rate of 2,000 pounds of vermiculite per hour)	Air	At the site: indoor and outdoor areas where vermiculite concentrate and waste material were handled	Inhalation	Former workers (Past)
	• Playing in piles of vermiculite concentrate or waste rock • Playing in rail cars full of vermiculite concentrate or waste rock • Loading and unloading vermiculite concentrate or waste rock for personal use	Air	At the site: stockpiles of vermiculite concentrate/waste material At home: where vermiculite concentrate/ waste material was unloaded	Inhalation	Community members (Past/present/future)
Residual asbestos on workers' clothing, hair, shoes	• Handling and laundering work clothes • Personal contact with workers who have not showered or changed clothes after work	Air	Workers' homes	Inhalation	Workers' families and other household contacts (Past)
Residual asbestos in soil or indoor dust at the site	• Activities that disturb or stir up indoor dust • Activities that disturb or stir up outdoor soil	Air	At the site: indoor and outdoor areas where amphiboles are present	Inhalation	Current workers (Present/future)
Residual asbestos in ambient air in the community	* *From plant emissions (stack emissions from the exfoliation furnace and fugitive emissions from material handling) during vermiculite processing*	Air	Ambient air around the site	Inhalation	Community members who live(d) or work(ed) near the site (Past/present/future)
Residual asbestos in offsite soil	* *From plant emissions or from vermiculite concentrate or waste material brought home for personal use* • Activities that disturb or stir up outdoor soil	Air	Offsite areas where vermiculite concentrate or waste material was used	Inhalation	
Residual asbestos in offsite indoor dust	* *From plant emissions or from vermiculite concentrate or waste material brought home for personal use* • Activities that disturb or stir up indoor dust	Air	Offsite residential and business locations near the site	Inhalation	

** Transport mechanisms: Residual asbestos could be present in off-site areas from (1) people taking vermiculite concentrate or waste material home for personal use or (2) environmental transport mechanisms (wind, storm water runoff) that moved asbestos from the site. Environmental transport mechanisms would reduce (or dilute) airborne and waterborne asbestos concentrations with increasing distance from the site.*

Table 3. Published reference levels for asbestos in air, soil, and dust

Medium	Reference level	Applicability / Comments	Reference
Air	1.0 f/cc	*Regulatory level. OSHA short-term exposure limit (STEL). This is the upper limit of exposure for a worker during a 30-minute period.*	OSHA 1994
	0.1 f/cc	*Regulatory level. OSHA permissible exposure limit (PEL). An 8-hour time-weighted average representing the limit of exposure for a worker during a normal work day.* OSHA's final rules for occupational exposure to asbestos acknowledged that "…a significant risk remains at the PEL of 0.1 f/cc". Instead of reducing the PEL even further, OSHA elected to eliminate or reduce this risk through mandated work practices, including engineering controls and respiratory protection for various classifications of asbestos-related construction and maintenance activities.	OSHA 1994
	0.01 f/cc	*Guidance level. Proposed as an acceptable threshold level for reoccupation of residential buildings for short-term (less than 1 year) exposure scenarios involving chrysotile asbestos. Continued monitoring and evaluation is recommended to determine if long-term access is acceptable.* An interagency workgroup composed of ATSDR, EPA, NIOSH, OSHA, New York State Department of Health, and New York City Department of Health scientists developed this guideline for World Trade Center 2001 response. It was established primarily for chrysotile exposure using OSHA regulatory guidelines and risk assessment using short-term exposure assumptions.	ATSDR 2003
	0.0009 f/cc (9×10^{-4} f/cc)	*Guidance level. A risk-based comparison value for chrysotile asbestos in indoor air developed to be protective under long-term residential exposure scenarios.* This guideline was developed primarily for chrysotile exposure using the current EPA cancer risk model and long-term (30-year) exposure assumptions.	EPA 2003a
	10^{-8}–10^{-4} f/cc	*Background level. Range of average concentrations of asbestos measured in ambient outdoor air.*	ATSDR 2001
Soil	≥1%	*Regulatory level. Soil containing asbestos at levels greater than or equal to 1% fits the definition of "asbestos-containing material" listed under several federal regulations. Once asbestos-containing materials have been identified, they must be managed in place or removed in accordance with these regulations.* The 1% level has been used as an action level for soil clean-up activities at a number of sites. However, the 1% action level is not a health-based standard.	EPA 1987 EPA 1990
	<1%	*Guidance level. Depending on site-specific exposure scenarios, remediation or other measures may be appropriate to prevent exposure to soils containing less than 1% asbestos.* Recent activity-based studies have shown that disturbing soil containing less than 1% asbestos can generate airborne asbestos concentrations at or near the OSHA PEL. Using a clean-up standard of 1% asbestos in soil will not be protective of human health in all cases. Site-specific factors critical to characterizing potential exposures associated with trace levels (<1%) of asbestos in soil include the frequency and type of activities that disturb the contaminated soil, the extent and type of ground cover, soil type, and soil moisture content.	EPA 2001 EPA 2004
	<0.25%	*Regulatory level. Two separate regulations in California use an asbestos content of greater than or equal to 0.25% to classify soil, rock, and other naturally-occurring materials as "restricted material" that cannot be used for road surfacing and must be managed appropriately during construction, grading, and other such activities.* Some states have specific guidance or regulations concerning asbestos levels in soil; other states do not.	CARB 2000 CARB 2001
Dust	5,000 AHERA s/cm^2	*An interim site-specific action level developed by EPA Region 8 for indoor residential scenarios in Libby, Montana.* This action level was developed using risk estimates for lifetime (70-year) exposure. Many uncertainties exist in the risk calculations because of the cancer risk model used and the re-suspension factors employed to describe how various household activities generate airborne asbestos from asbestos-containing dust. The action level is expressed in terms of AHERA s/cm^2 to indicate that samples should be analyzed by transmission electron microscopy (TEM) using AHERA counting rules (counting structures longer than 0.5 µm with aspect ratios greater than 3:1).	EPA 2003b

Table 3, continued. Published reference levels for asbestos in air, soil, and dust

Definitions

OSHA	Occupational Safety and Health Administration	NIOSH	National Institute of Occupational Safety and Health	f/cc	fibers per cubic centimeter of air
ATSDR	Agency for Toxic Substances and Disease Registry	CARB	California Air Resources Board	s/cm^2)	structures per square centimeter
EPA	Environmental Protection Agency	AHERA	Asbestos Hazard Emergency Response Act	s/cc	structures per cubic centimeter

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Table 4. Site information for the 28 sites ATSDR evaluated

ATSDR/ EPA Region	Facility Location	Facility name during vermiculite processing operations	Estimated timeframe for processing VC from Libby*	Estimated number of former employees†	Population within 1 mile radius, 1990 census‡	Interior sampling/ cleanup (recent)	Exterior sampling/ cleanup (recent)	Site currently in use? §
1	Easthampton, MA	Zonolite Company (Co.)/W.R. Grace & Co. (WRG)	1963–1984	20–23	2,544	No / No	Yes / No	Yes
2	Edgewater, NJ	Celotex	1967–1969	—	29,845	No / No	Yes / No	Yes
2	Hamilton Township, NJ	Zonolite Co./WRG	1948–early 1990s	—	9,080	No / No	Yes / Yes	No
2	Weedsport, NY	Zonolite Co./WRG	1963–1989	8–10	1,267	No / No	Yes / No	No
3	Beltsville, MD	Zonolite Co./WRG	1966– early 1990s	14	320	Yes / No	Yes / No	Yes
3	Ellwood City, PA	Zonolite Co./WRG	1954–1969	12	6,625	Yes / No	Yes / Planned	Yes
3	New Castle. PA	WRG	1969–1992	18	2,196	Yes / No	Yes / Yes	No
4	Tampa, FL	Zonolite Co./WRG	1950s–1991	2–10	4,645	Yes / No	Yes / No	Yes
4	Wilder, KY	Zonolite Co./WRG	1952–1992	10–30	9,095	Yes / Yes	Yes / Yes	Yes
5	West Chicago, IL	WRG	1974–early 1990s	15–35	3,065	No / No	Yes / No	Yes
5	Dearborn, MI	Zonolite Co./WRG	early 1950s–1989	15–25	25,539	Yes / Yes	Yes / Yes	Yes
5	Minneapolis, MN	Western Mineral Products Co.	1936-1989	11–52	21,509	Yes / Yes	Yes / Yes	Yes
5	Marysville, OH	O.M. Scott & Sons	1963–1980	—	185	Yes / No	Yes / No	Yes
6	New Orleans, LA	Zonolite Co./WRG	1965–1989	8–12	5,047	No / No	No / No	Yes (2005)
6	Dallas, TX	Texas Vermiculite Co./WRG	1953–1992	16–42	7,140	Yes / No	Yes / No	No
7	St Louis, MO	Zonolite Co./WRG	1944–1988	12–19	13,609	No / No	Yes / No	Yes
7	Omaha, NE	Western Mineral Products Co.	1940s–1989	5–24	121	No / No	Yes / No	Yes
8	Denver, CO	Western Mineral Products Co.	1950–1990	4–11	12,822	Yes / No	Yes / Yes	Yes
8	Minot, ND	Robinson Insulation Co.	1945–1983	—	9,484	Yes / Yes	Yes / Yes	Yes
9	Glendale, AZ	Ari-Zonolite Co.	1951–1964	—	16,642	Yes / Yes	Yes / No	No
9	Phoenix, AZ	WRG	1964–1992	—	12,915	Yes / Yes	Yes / Yes	Yes
9	Glendale (L.A.), CA	California Zonolite/WRG	1950–1977	19	1,748	Yes / Yes	Yes / Yes	Yes
9	Newark, CA	WRG	1966–1993	18–30	10,183	Yes / Yes	Yes / Yes	Yes
9	Santa Ana, CA	WRG	1971–1993	—	35,832	Yes / No	Yes / No	Yes
9	Honolulu, HI	Vermiculite of Hawaii	1954–1983	—	23,317	Yes / Yes	Yes / Yes	Yes
10	Portland, OR	Vermiculite Northwest, Inc./WRG	early 1950s–1993	13–21	8,316	Yes / Yes	Yes / Yes	Yes
10	Portland, OR	Supreme Perlite Co. (Suttle Road)	1968–1974	3–6	139	Yes / No	Yes / Yes	Yes
10	Spokane, WA	Vermiculite Northwest, Inc./WRG	1940s–1974	21	17,214	Yes / Yes	Yes / Yes	No

* Best estimate for timeframe that the facility handled or processed vermiculite concentrate from Libby, Montana, based on invoice data and site-specific information.

† Estimates represent the number of employees at a given point in time. The total number of employees over time would depend on the number of employees at the facility, the turnover rate for the employees, and the number of years the facility operated. "—" indicates no information is available.

‡ Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.

§ Current site status may have changed since this information was collected.

Appendix A. Vermiculite exfoliation sites that may have received vermiculite concentrate from Libby, Montana

ATSDR assembled the following list of 105 vermiculite exfoliation sites that may have received vermiculite concentrate (VC) from the Libby mine (Table A-1). This list is intended as a reference for follow-up activities by site owners or by federal, state, and local authorities as needed. ATSDR is not implying that each of these sites is contaminated with asbestos.

Several important limitations and clarifications should be considered when using Table A-1.

- Many of the site names refer to the facility or company that exfoliated VC. These companies may no longer exist.
- Site addresses were adopted from existing documentation. ATSDR did not field-verify addresses and cannot attest to their accuracy.
- The VC tonnage information is from W.R. Grace invoice data available for 1964–early 1990s. Invoice data were not available before 1964. The available information may underestimate or overestimate actual tonnage received by these facilities (reference discussion section of this report for more information on invoice data limitations).
- Some sites have no tonnage information listed. This does not mean that the site did not receive VC from Libby. It simply means that no invoice data were available to confirm shipments of VC from Libby to the site.
- The current vermiculite exfoliation facilities listed obtain their VC from other active domestic and foreign vermiculite mines, not from Libby (the Libby mine closed in 1990).

ATSDR used the following sources of information to assemble the list of vermiculite exfoliation facilities:

- The EPA list of 245 sites that may have received VC from Libby (EPA, unpublished data, 2003).
- The EPA summary of W.R. Grace invoices for VC shipped from the Libby mine (EPA, unpublished data, 2001).
- An early EPA list of sites that may have received VC from Libby (EPA, unpublished data, 2000).
- BOM and USGS historical vermiculite information available at http://minerals.usgs.gov/minerals/. Historical Minerals Yearbook information (1932–1993) as well as the Mineral Commodity Summaries for vermiculite (1996–2006) were utilized.
- Site-specific information from EPA and ATSDR site visits
- W.R. Grace records for licensees and independent exfoliation companies (EPA, unpublished data, 2000)
- Supplemental information provided by EPA on June 30, 2008.

Table A-1. Vermiculite exfoliation sites that may have received vermiculite concentrate from Libby, Montana

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
1	Zonolite Co/WR Grace	PO Box 117	Billerica	Middlesex	**MA**	01862	XF	1964	--	--
1	Zonolite Co/WR Grace	62 Whittemore Avenue	Cambridge	Middlesex	**MA**	02140	XF	1999	11,495	11,495
1	Zonolite Co/WR Grace	Wemelco Way	Easthampton	Hampshire	**MA**	01027	XF	1964,1970, 1975, 1980, 1985, 1990	183,255	183,255
2	Zonolite Co/WR Grace	35 Industrial Way	Hamilton Township	Mercer	**NJ**	08619	XF	1953 1964 1970 1975 1980 1985 1990	317,870	317,870
2	American Vermiculite Products Corp		Kearney	Hudson	**NJ**	07032	XF	1953	--	--
2	Coralux/Schundler Co	150 Whitman Ave	Metuchen	Middlesex	**NJ**	08840	XC	1970 1975 1980 1985 1990 1999 2004	--	--
2	Vermiculite Industrial Corp	Gilligan St, Bldg 8 (Navy Area)	Newark	Essex	**NJ**	07114	XF	1953, 1964, 1970	760	760
2	Zonolite Co/WR Grace	N Ferry and Water Sts	Albany	Albany	**NY**	12207	XF	1953	--	--
2	FE Schundler & Co, Inc	45-15 Vernon Blvd	Long Island	Queens	**NY**	11101	XF	1953	--	--
2	The Carborundum Co	1625 Buffalo Ave	Niagara Falls	Niagra	**NY**	14303	XF	1953	--	--
2	Zonolite Co/WR Grace	One Clay St	Utica	Oneida	**NY**	13501	XF	1963 1964	--	--
2	Zonolite Co/WRG	Dunn Road	Weedsport	Cayuga	**NY**	13166	XF	1964 1970 1975 1980 1985	148485 1,3330	149,815
3	Vermiculite Products Co/WR Grace	1911 Kenilworth Ave NE	Washington, DC (also, Kenilworth/ Beaver Heights, MD)	District of Columbia	**DC**	20019	XF	1953	--	--
3	Zonolite Co/WR Grace	12340 Conway Rd	Beltsville (Muirkirk)	Prince Georges	**MD**	20705	XF	1970 1975 1980 1985 1990	93,005 95	93,100
3	J.P. Austin (A-Tops Mfg)	1060 24th St	Beaver Falls	Beaver	**PA**	15010	XC	1975 1980 1985 1990 1999	--	--
3	Harbison-Walker Refractories Co	600 Bigler Rd	Clearfield	Clearfield	**PA**	16830	XF	1953	--	--
3	Zonolite Co/WR Grace	12 & Factory St	Ellwood City	Lawrence	**PA**	16117	XF	1964	9,500	9,500
3	Zonolite Co/WRGrace	202 E Cherry St	New Castle	Lawrence	**PA**	16102	XF	1970 1975 1980 1985 1990	172,140	172,140
3	Therm-o-Rock/Allied Block Chemical, Inc	Pine St	New Eagle/ Monongahela	Washington	**PA**	15067	XC	2004	475	475
3	Zonolite Co	23 & PA RR	Pittsburgh (also Sharpsburg)	--	**PA**	16150	XF	1953	--	--

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
3	Hyzer and Lewellen	662 Belmont Ave	Southampton	Bucks	**PA**	18966	XF	1953 1964 1970 1975	--	--
4	Southern Zonolite Co/WR Grace	2800 5th Ave S	Birmingham	Jefferson	**AL**	35233	XF	1953 1964	200	200
4	Zonolite Co/WR Grace	2601 Commerce Blvd	Irondale	Jefferson	**AL**	35210	XF	1985 1990	57,760	57,760
4	Zonolite Co/WRGrace/Seaboard Vermiculite	1700 NW 1st Court	Boca Raton	Palm Beach	**FL**	33432	XF	--	115	115
4	WR Grace	1050 SE 5th St	Hialeah	Dade	**FL**	33010	XF	--	--	--
4	Southern Zonolite Co/WR Grace	1530 E Adams St	Jacksonville	Duval	**FL**	32202	XF	1953 1964 1970 1975 1980 1985 1990	935 5,400	6,335
4	Zonolite Co/WR Grace	1200 NW 15th Ave	Pompano Beach	Broward	**FL**	33069	XF	1975 1980 1985 1990 1999	9,975	9,975
4	Verilite	3401 E 3rd Ave	Tampa	Hillsborough	**FL**	33605	XF	--	--	--
4	Zonolite/WR Grace	35th and 3rd Ave (3401 N. 3rd Ave)	Tampa	Hillsborough	**FL**	33605	XC	1964 1970 1975 1980 1985 1990 1999	112,005 96	112,102
4	Southern Zonolite/WRG/Verilite Co.	6211 N 56th St.	Tampa	Hillsborough	**FL**	33610	XC	1953 1964 1970 1975 1980 1985 1990	--	--
4	Zonolite Co/WR Grace	1167 Zonolite Pl NE	Atlanta	Fulton	**GA**	30340	XF	1964	480	480
4	Anitox Corp	1885 Anitox Dr	Buford	Gwinnett	**GA**	30519	XF	1990	--	--
4	Anitox Corp	955 Hurricane Shoals Road	Lawrenceville	Gwinnett	**GA**	30043	XF	1990	--	--
4	WR Grace/Diversified Insulation	Box 546	Savannah	Chatham	**GA**		XF	--	42	42
4	Zonolite Co/WR Grace Wilder Plant	112 North St	Wilder	Campbell	**KY**	41071	XF	1953 1964 1970 1975 1980 1985 1990	222,110	222,110
4	Southern Vermiculite	Unknown	Franklin	Macon	**NC**	28734	XF	1953	--	--
4	Zonolite Co/WR Grace	1701 Prospect St	High Point	Guilford	**NC**	27260	XF	1964 1970 1975 1980 1985	8,550	8,550
4	American Vermiculite Minerals, Inc.	Unknown	Spruce Pine	Mitchell	**NC**	28777	XF	1953	--	--
4	WR Grace	26383 Hwy 221 North	Enoree	Laurens	**SC**	29335	XC	1975 1980 1985 1990 1999	9,600	9,600
4	Zonolite Co/WR Grace	830 Hwy 25 Bypass	Traveller's Rest	Greenville	**SC**	29690	XC	1953 1964 1970 1975 1980 1985 1990	17,005	17,005
4	Palmetto Vermiculite Co/Enoree Minerals	13101 Hwy 221	Woodruff	Spartanburg	**SC**	29388	XC	1999	--	--

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
4	Zonolite Co/WR Grace	4061 Powell Ave	Nashville	Davidson	**TN**	37204	XF	1953	29,545	29,545
5	Zonolite Co/WR Grace	603 Fenton Lane W	West Chicago	Du Page	**IL**	60185	XF	1964 1975 1980 1985 1990	273600 380	273,980
5	W. R. Grace	12300 South Ashland St	Chicago/Blue Island		**IL**	60827	XF	1953	67,355	67,355
5	FE Schundler & Co/Mica Pellets, Inc	1008 Oak St	De Kalb	De Kalb	**IL**	60115	XF	1953 1970 1975 1980	17,100 27,645	44,745
5	International Vermiculite Co/Thermic Refractories/Thermal Ceramics	115 E Mound St	Girard	Macoupin	**IL**	62640	XF	1953 1964 1970 1975 1980	9,300 26,100 15,770 665	51,835
5	FE Schundler & Co	504 Railroad St	Joliet	Will	**IL**	60436	XF	1953	--	--
5	Strong-Lite Products Corp (Sun Gro Horticulture Inc)	444 Shipyard Rd	Seneca	La Salle	**IL**	61360	XF	1985 1990 1999	190	190
5	Zonolite Co/WR Grace	14300 Henn St	Dearborn	Wayne	**MI**	48120	XF	1953 1964 1970 1975 1980 1985 1990	206,055	206,055
5	MacArthur Co	936 Raymond Ave	St Paul	Ramsey	**MN**	55114	XF	1953 1964 1970 1975	13,720	13,720
5	BF Nelson Mfg	401 Main St, NE	Minneapolis	Hennepin	**MN**	55413	XF	1953 1964 1970	4,785	4,785
5	Certain Teed Products	459 Harding St NW	Minneapolis	Hennepin	**MN**	55413	XF	--	2,750 2,450 975 1,200	7,345
5	Western Mineral Products (WRG)	1720 Madison St NE	Minneapolis	Hennepin	**MN**	55413	XF	1953 1964 1970 1975 1980 1985	118,465 4,365	122,830
5	Wyodak Chem Co.	4600 E 71st St	Cleveland	Cuyahoga	**OH**	44125	XF	1953	--	--
5	O.M. Scott Assoc Co, Inc.	14111 Scottslawn Rd	Marysville	Union	**OH**	43040	XF	1980 1985 1990 1999	429,495	429,495
5	PVP Industries, Inc.	Box 129 9819 Penniman Rd	N Bloomfield	Trumbull	**OH**	44450	XC	1999 2004	570 1,140	1,710
5	Vermiculite Industrial	51887 E Taggart St	Palestine	Columbia	**OH**	44413	XF	--	95	95
5	Koos, Inc	4500 13th Court	Kenosha	Kenosha	**WI**	53140	XF	1975 1980 1985 1990	475 1,520	1,995
5	Western Mineral Products Co (WRG)	525 W Oregon St	Milwaukee	Milwaukee	**WI**	53204	XF	1953 1964 1970 1975 1980	3,135	3,135
5	W. R. Grace/Const Products Division	Grand Ave District Yard	Milwaukee	Milwaukee	**WI**	53213	XF	--	63,175	63,175
5	Koos, Inc.	2000 DeKovan Ave	Racine	Racine	**WI**	53403	XF	--	--	--
6	Scott's Co, Hyponex	3713 Hwy 32 N	Hope	Hempstead	**AR**	71801	XF	--	1,152	1,152
6	Zonolite Co/WR Grace	Dixie Rd	Little Rock	Pulaski	**AR**	72115	XF	1953 1964 1970 1975 1980 1985	85,050	85,050

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
6	Strong-Lite Products Sun Gro Horticulture Inc.)	4418 Emmitt Sanders Rd	Pine Bluff	Jefferson	**AR**	71601	XC	1975 1980 1985 1990 1999	386	386
6	Southern Mineralite Co/WR Grace	2933 Dauphine St	New Orleans	Orleans	**LA**	70117	XF	1953 1964 1970 1975 1980 1985	--	--
6	Zonolite Co/WR Grace	4729 River Rd	New Orleans	Jefferson	**LA**	70121	XF	--	148,295	148,295
6	Filter Media Co	W. 10 St	Reserve	St John the Baptist	**LA**	70084	XF	1970		
6	Solico, Inc (Southwest Vermiculite)	5119 Edith Blvd NE	Albuquerque	Bernalillo	**NM**	87107	XC	1999	97	97
6	Southwest Vermiculite Co	1822 N First St	Albuquerque	Bernalillo	**NM**	87102	XF	1953 1964 1970	68,305	68,305
6	Zonolite Co/WR Grace/TX, OK Vermiculite	200 N Wisconsin Ave	Oklahoma City	Oklahoma	**OK**	73117	XF	1964 1970 1975 1980 1985	81,415 30,780 1,710	113,905
6	Voluntary Purchasing Co.	Highway 82 West	Bonham	--	**TX**	75418	XF	--	93 48,355	48,449
6	Texas Vermiculite Co	State Hwy 29	Burnet	Burnet	**TX**	78611	XF	1953	--	--
6	Texas Vermiculite Co (WRG 1975)	2651 Manila Rd	Dallas	Dallas	**TX**	75212	XF	1964 1970 1975 1980 1985 1990	78,755 318,155	396,910
6	Isolatek Intl	2240 Bingle Rd	Houston	Harris	**TX**	77055	XC	--	--	--
6	Tri-Lite Corp	2624 Link Road	Houston	Harris	**TX**	77009	XF	1964	--	--
6	Vermiculite Products, Inc	Box 7327, 3025 Maxroy St (Greer Spur)	Houston	Harris	**TX**	77008	XC	1964 1970 1975 1980 1985 1990 1999	207,670 1,900 3,610 600	213,780
6	Texas Lightweight Products	117 N Britain Rd	Irving	Dallas	**TX**	75060	XF	--	--	--
6	Volite Co	Box 122, N Hwy 16	Llano	Llano	**TX**	78643	XF	--	--	--
6	Texas Vermiculite Co (WRG)	354 Blue Star St	San Antonio	Bexar	**TX**	78204	XF	1964 1970 1975 1980 1985	83,695 40,850	124,545
7	Diversified Insulation/Shelter Shield/WRG	4814 Fiber Lane	Wellsville	Franklin	**KS**	66092	XF	1980	3,420 570	3,990
7	Dodson Manufacturing Co	1463 Barwise St	Wichita	Sedgwick	**KS**	67214	XF	1953 1964	--	--
7	Eagle-Picher Lead Co Insulation Division	1220 NW Murphy Ave	Joplin	Jasper	**MO**	64801	XF	1953	--	--
7	Zonolite Co/WR Grace	515 Madison St	Kansas City	Jackson	**MO**	64105	XF	1953	2,460	2,460
7	J.J. Brouk	1367 S Kingshighway Blvd	St Louis	St Louis City	**MO**	63110	XF	1975 1980 1985 1990	24,150 5,415	29,565

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
7	Zonolite Co/WR Grace	1705 Sulphur Avenue	St Louis	St Louis City	**MO**	63110	XF	1953 1964 1970 1975 1980 1985 1990	139,460	139,460
7	Western Mineral Products Co/Douglas	3520 South I Street	Omaha		**NE**	68107	XF	1953 1970 1975 1980 1985	161,310 4,560 97 500	166,468
8	Western Mineral Products Co (WRG)	111 S Navajo St	Denver	Denver	**CO**	80223	XF	1953 1964 1970 1975 1980 1985 1990	100,415 2,565	102,980
8	Robinson Insulation Co	12th St N and River Dr	Great Falls	Cascade	**MT**	59401	XF	1953 1964 1970 1975 1980 1985	288 33,725	34,013
8	Robinson Insulation Co	826 4th Avenue NE	Minot	Ward	**ND**	58701	XF	1953 1964 1970 1975 1980	16,150	16,150
8	Vermiculite Intermountain	333 W 100 St	Salt Lake City	Salt Lake	**UT**	84101	XF	1953 1964 1970 1975 1980 1985	193 4,940 550 27,350 150 500 15,150 95	33,930
8	Intermountain Insulation Co	733 West 800 South	Salt Lake City	Salt Lake	**UT**	84101	XF	1953	--	--
9	Therm-o-Rock Ind	6732 W Willis Rd	Chandler	Maricopa	**AZ**	85226	XC	1999	--	--
9	Ari-Zonolite	6960 52nd Ave	Glendale	Maricopa	**AZ**	85301	XF	1953 1964 1970	--	--
9	WRG/Diversified Insulation WRG	4220 W Glenrosa Ave	Phoenix	Maricopa	**AZ**	85019	XC	1970 1975 1980 1985 1990 1999	254,885	254,885
9	La Habra Products, Inc	1631 W Lincoln Ave	Anaheim	Orange	**CA**	92805	XF	1964 1970 1975	--	--
9	California Zonolite Co/WR Grace	5440 West San Fernando Rd	Los Angeles	Los Angeles	**CA**	90039	XF	1953 1964 1975 1980	82,080 38,130	120,210
9	CA Zonolite/Divers Insul/WRG/Steeler Inc	6851 Smith Ave	Newark	Alameda	**CA**	94560	XF	1970 1975 1985 1990	312,075 25,000	337,075
9	California Zonolite Co/WR Grace	208 Jibboom St	Sacramento	Sacramento	**CA**	95814	XF	1953 1964	--	--
9	Arabian American Oil	22 Battery Street	San Francisco	San Francisco	**CA**	24111	XF	1953	--	--
9	WRG/Diversified Insul.	2502 S Garnsey St	Santa Ana	Orange	**CA**	92707	XF	1975 1980 1985 1990	421,515 31,445	452,960
9	Vermiculite of Hawaii Inc.	842A Mapunpuna St	Honolulu	Honolulu	**HI**	96819	XF	1964 1970 1975 1980	170	170
9	U.S. Gypsum Co	100 1st St	Gerlach/Empire	Washoe	**NV**	89405	XF, G	--	2500 52.8	2,553

Region*	Vermiculite facility name*	Address*	City*	County*	State*	Zip code†	Type of Facility‡	Year listed as exfoliation facility by BOM/USGS§	Tonnage of vermiculite¶	Total Tonnage of vermiculite¶
10	Vermiculite NW, Inc (WR Grace)	2302 N Harding Ave	Portland	Multnomah	**OR**	97227	XF	1953 1964 1970 1975 1980 1985 1990	185,915 12,540	198,455
10	Supreme Perlite Co	4600 North Suttle Rd	Portland	Multnomah	**OR**	97217	XF	1964 1970 1975	660	660
10	Vermiculite - NW, Inc (WR Grace)	1318 Maple St	Spokane	Spokane	**WA**	99201	XF	1953 1964 1970	9,785 5,425	15,210

* This information was derived from an EPA list of sites that may have received vermiculite from Libby, Montana. All of the sites listed were identified from the last revision of the EPA site list, dated April 24, 2003.

† Zip code information either was adopted from the EPA site list information or was derived from geo-referencing street or city identifiers.

‡ Type of facility was determined based upon past and current Bureau of Mines/USGS Minerals Yearbook information, site-specific information from EPA and ATSDR site visits, W.R. Grace records for licensees and independent exfoliation companies, and limited Internet research.
XF = former exfoliation site; XC = current exfoliation site; M = mine site, G=gypsum board manufacturing facility

§ This information was adopted from early EPA lists of sites that may have received vermiculite from Libby, Montana. ATSDR did not verify all of this information against historical BOM/USGS records.

¶ The tonnage of vermiculite attributed to each site was derived from EPA's summary information of W.R. Grace & Company shipping invoices for the Libby mine (approximately 1964–early 1990s).

"--"indicates that no information is available

Yellow shading indicates sites that ATSDR and state health departments evaluated previously (see Appendix B of this report). A detailed report for each of the sites is available at http://www.atsdr.cdc.gov/asbestos/sites/national_map.

Appendix B. Site Profiles

A one-page profile for each of the 28 sites ATSDR evaluated is included in this appendix. The sites are listed by region.

ATSDR/EPA Region 1

Former Zonolite Company/W.R. Grace & Company
Wemelco Way
Easthampton, Hampshire County, Massachusetts

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1963–1984
Estimated amount of VC received from Libby, Montana: 183,300 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1984.)
Approximate number of employees at a given time (during vermiculite processing): 20–23
Population within a 1-mile radius of the site in 1990: 2,544
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2.5 acre site is commercial and residential. The site is currently being used for light industrial operations unrelated to vermiculite exfoliation. Development of a community bike path (rails-to-trails) along the railroad bed on the southern boundary of the property has been proposed.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1974–1991*	Personal and area (engineering) samples

* This is an estimate based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1992	Indoor air (after plant closure)
J.P. Stevens Elastomerics*	2000	Indoor bulk samples from walls, floor, insulation
EPA Region 1, MA DEP	2000	Soil
EPA Region 1, MA DEP	2000–2001	Soil, sediment, ambient air, personal air samples for workers conducting sampling

* Current lessee of the warehouse at the site.

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Note: The health consultation report issued by ATSDR and Massachusetts Department of Public Health in December 2006 recommends several actions intended to reduce or eliminate potential exposure at the site, including site access restrictions, additional soil sampling, air monitoring during employee operations, and air monitoring and dust suppression measures during any site development activities.

Lead public health agency for health consultation: Massachusetts Department of Public Health

ATSDR/EPA Region 2
Celotex Corporation
1 River Road
Edgewater, Bergen County, New Jersey

Type of facility: Gypsum wallboard manufacturing
Estimated timeframe for processing VC from Libby: 1967–1969
Estimated amount of VC received from Libby, Montana: 300 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1969.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 29,845
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 29.5 acre site is in an area of industrial, commercial, and residential land use. The site itself was redeveloped for residential and commercial use during the 1990s.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 2	2000	Soil

Remediation (cleanup) conducted at the site? No

Note: The Celotex site is adjacent to a 16-acre site, owned by Quanta Resources Corporation, which was added to the U.S. Environmental Protection Agency National Priority List of Superfund sites in 2001. New Jersey Department of Health and Senior Services, in conjunction with ATSDR, reviewed environmental data from the Quanta site as well as from neighboring properties, including the Celotex site, and developed a Public Health Assessment report in 2002.[1]

Lead public health agency for health consultation: New Jersey Department of Health and Senior Services

[1] ATSDR. Public Health Assessment: Quanta Resources Corporation, Edgewater, Bergen County, New Jersey. Prepared for ATSDR by New Jersey Department of Health and Senior Services. Atlanta: US Department of Health and Human Services; Sept 2002.

ATSDR/EPA Region 2

Former Zonolite Company/W.R. Grace & Company
35 Industrial Way
Hamilton Township, Mercer County, New Jersey

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1948–early 1990s
Estimated amount of VC received from Libby, Montana: 204,821 tons
(Source: EPA Region 2 interpretation of available invoices from W.R. Grace & Company during 1966–1988.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 9,080
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The property is comprised of two separate lots on 8.44 acres. The building used in the past for vermiculite processing activities was situated on the northwestern lot. It was last used by a document recycling company until it was destroyed by a fire in April 2005. The southeastern lot is 4.2 acres of heavily wooded land cover. Land use surrounding the site is primarily industrial. The nearest residential area is ¼ mile to the west of the site.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976–1986*	Personal and area (engineering) samples

* This is an estimate based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1995	Indoor air (after plant closure)
EPA Region 2	2000	Soil
EPA Region 2	2001	Soil
EPA Region 2	2005	Ambient air (during and after building fire)
EPA Region 2	2006	Soil samples were collected from 22 residential properties within ½ mile of the site and 22 public recreation areas within 2 miles of the site.

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
EPA Region 2	2004	Excavation and removal of exterior soil contaminated with amphiboles

Note: ATSDR collaborated with state health departments to offer medical screening to former workers and their household contacts at selected vermiculite sites across the U.S., including the site in Hamilton Township, New Jersey. Results of the medical screening will be published in a separate report.

Lead public health agency for health consultation: New Jersey Department of Health and Senior Services

ATSDR/EPA Region 2

Former Zonolite Company/W.R. Grace & Company
Dunn Road
Weedsport (Brutus), Cayuga County, New York

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1963–1989
Estimated amount of VC received from Libby, Montana: 114,467 tons
(Source: EPA Region 2 interpretation of available invoices from W.R. Grace & Company during 1966–1991.)
Approximate number of employees at a given time (during vermiculite processing): 8–10
Population within a 1-mile radius of the site in 1990: 1,267
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 1.6 acre site is surrounded by agricultural, residential, and undeveloped land. The site has been used for industrial operations unrelated to vermiculite exfoliation following closure of the exfoliation plant in 1989. It has been vacant since 2001, and was available for lease or sale in 2006.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976–1988*	Personal and area (engineering) samples

* This is an estimate based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1989	Indoor air (after plant closure)
EPA Region 2	2001	Soil
EPA Region 2	2002, 2003	Soil from two properties where exfoliation waste was reportedly disposed

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: New York State Department of Health

ATSDR/EPA Region 3

Former Zonolite Company/W.R. Grace & Company
12340 Conway Road
Beltsville, Prince Georges County, Maryland

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1966–early 1990s
Estimated amount of VC received from Libby, Montana: 93,100 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1988.)
Approximate number of employees at a given time (during vermiculite processing): 14
Population within a 1-mile radius of the site in 1990: 320
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 1.74 acre site is in an industrial area. Residential areas are located approximately ½ mile south and southwest of the site. The site has been used for industrial operations unrelated to vermiculite exfoliation since the exfoliation plant closed in the early 1990s.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976–1990*	Personal and area (engineering) samples

* This is an estimate based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1996	Indoor air (after plant closure)
EPA Region 3	2000	Soil, bulk material from inside the facility
EPA Region 3	2002	Soil, indoor air, bulk material from inside the facility

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 3

Former Zonolite Company/W.R. Grace & Company
12th and Factory Street
Ellwood City, Lawrence County, Pennsylvania

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1954–1969
Estimated amount of VC received from Libby, Montana: 9,500 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1969.)
Approximate number of employees at a given time (during vermiculite processing): 12
Population within a 1-mile radius of the site in 1990: 6,625
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 2 acre site is in an area of mixed industrial, commercial, and residential land use. The site has been used for various industrial operations unrelated to vermiculite exfoliation following closure of the exfoliation plant.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 3	2000	Bulk material
EPA Region 3	2002	Indoor air, soil
EPA Region 3	2006	Soil

Remediation (cleanup) conducted at the site? Soil cleanup planned for Spring 2008 (EPA Region 3).

Note: Anecdotal reports from community members indicate that neighborhood children gathered daily at a playground located on the site in the past, when the facility exfoliated vermiculite. On the basis of information from community members about past plant practices involving waste disposal, EPA collected additional soil samples from the site in 2006. Remediation decisions for the site will be determined on the basis of sample results, current and future site use, and stakeholder input.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 3
W.R. Grace & Company
202 East Cherry Street
New Castle, Lawrence County, Pennsylvania

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1969–1992
Estimated amount of VC received from Libby, Montana: 172,100 tons
(Source: Available invoices from W.R. Grace & Company during 1969–1988.)
Approximate number of employees at a given time (during vermiculite processing): 18
Population within a 1-mile radius of the site in 1990: 2,196
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 2.5 acre site is in an area of light commercial and residential land use. A residential area a few hundred feet north of the site was present before the facility began processing vermiculite. The site was not used from the time exfoliation operations ceased in 1992 until remediation was completed in 2004.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1972–1988*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1996	Indoor air (after plant closure)
W.R. Grace	1998, 1999	Soil
EPA Region 3	2000	Indoor dust, bulk material inside the facility
EPA Region 3	2002	Soil
W.R. Grace	2003	Soil, indoor air

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
W.R. Grace	2004	Excavated and removed 7,890 tons of asbestos-containing soil.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 4
Former W.R. Grace & Company
3401 North 3rd Avenue
Tampa, Hillsborough County, Florida

Type of facility: Vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1950s–1991
Estimated amount of VC received from Libby, Montana: 112,100 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1991.)
Approximate number of employees at a given time (during vermiculite processing): 2–10
Population within a 1-mile radius of the site in 1990: 4,645
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 1.5 acre site is in an area of commercial and light industrial land use. Several residential properties are located less than ¼ mile from the site. A residential area is located approximately ¼ mile north of the site. The site currently is being used for exfoliation of vermiculite that is predominantly from South Africa.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976,1979*	Personal and area (engineering) samples
National Institute for Occupational Safety and Health	2002	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1993	Indoor air (after plant closure)
EPA Region 4	2001	Soil
National Institute for Occupational Safety and Health	2002	Indoor air, bulk material

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	1993	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal. At the Tampa site, exfoliation furnaces were left at the site and are currently being used.

Lead public health agency for health consultation: Florida Department of Health

ATSDR/EPA Region 4
Former Zonolite Company/W.R. Grace & Company
112 North Street
Wilder, Campbell County, Kentucky

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1952–1992
Estimated amount of VC received from Libby, Montana: 220,100 tons
(Source: Available invoices from W.R. Grace & Company during 1953–1988.)
Approximate number of employees at a given time (during vermiculite processing): 10–30
Population within a 1-mile radius of the site in 1990: 9,095
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 5.4 acre site is primarily light industrial. The nearest residential area is over ¼ mile from the site. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976–1989*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1996	Indoor air (after plant closure)
W.R. Grace	2000	Soil
EPA Region 4	2002	Indoor air, soil
EPA Region 4	2004	Indoor dust
EPA Region 4	2004	Indoor air

Remediation (cleanup) conducted at the site? Yes.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
EPA Region 4	2004	Indoor surfaces were cleaned using high-efficiency particulate air (HEPA) vacuums and wet methods.
EPA Region 4	2004	Approximately 26,400 tons of asbestos-containing material were excavated and removed from the site.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 5
Former W.R. Grace & Company
603 Fenton Lane
West Chicago, DuPage County, Illinois

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1974–early 1990s
Estimated amount of VC received from Libby, Montana: 273,600 tons
(Source: Available invoices from W.R. Grace & Company during 1974–1988.)
Approximate number of employees at a given time (during vermiculite processing): 15–35
Population within a 1-mile radius of the site in 1990: 3,065
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 6.4 acre site is primarily commercial and industrial. The nearest residential area is 1/2 mile east of the site. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1986–1991*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1996	Indoor air (after plant closure)
EPA Region 5	2001	Soil

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: Illinois Department of Public Health

ATSDR/EPA Region 5
Former W.R. Grace & Company
14300 Henn Street
Dearborn, Wayne County, Michigan

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: early 1950s–1989
Estimated amount of VC received from Libby, Montana: 206,100 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1988.)
Approximate number of employees at a given time (during vermiculite processing): 15–25
Population within a 1-mile radius of the site in 1990: 25,539
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2.7 acre site includes recreational, residential, educational, industrial, and commercial developments. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1986–1989*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1990	Indoor air (after plant closure)
EPA Region 5	2003	Soil, indoor air, bulk material from inside the facility

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
Site owner (Die, Mold, & Automation Components, Inc.)	2004	Bulk material containing asbestos inside the facility was removed by a certified asbestos contractor.
EPA Region 5	2005	Excavated an d removed 1,450 cubic yards of asbestos-containing soil from the site; visited 1,030 homes and businesses around the site; inspected 163 residential yards and collected samples at 50 of them. No asbestos contamination was found in residential yards.

Lead public health agency for health consultation: Michigan Department of Community Health

ATSDR/EPA Region 5
Former Western Mineral Products
1720 Madison Street NE
Minneapolis, Hennepin County, Minnesota

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1936–1989
Estimated amount of VC received from Libby, Montana: 122,800 tons
(Source: Available invoices from W.R. Grace & Company during 1951–1988.)
Approximate number of employees at a given time (during vermiculite processing): 11–52
Population within a 1-mile radius of the site in 1990: 21,509
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 4 acre site is residential, commercial, and light industrial. The site currently is used for commercial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1972–1989*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1989	Indoor air (after plant closure)
EPA Region 5	2000–2001	At the site: soil, indoor air, ambient air, personal At locations around the site: soil, ambient air
W.R. Grace	2000	Soil, indoor air, dust and debris inside the facility
EPA Region 5	2000–2006	Personal and work area samples collected during remediation activities at residential locations and at a public park near the site where waste material was applied as fill.

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	1989	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
EPA Region 5	2000–2001	Excavated and removed 6,000 cubic yards of contaminated soil at the site, cleaned indoor areas.
EPA Region 5	2000–2006	Inspected 1,700 properties around the site and in the Northeast Minneapolis area, cleaned up 260 residential yards, and excavated 15,000 tons of contaminated soil at a park where waste material was applied as fill.

Note: Minnesota Department of Health (MDH) developed an exposed cohort of 6,700 community members, workers, and worker family members associated with this site and conducted extensive outreach and education to community members and health care providers in the area. ATSDR collaborated with state health departments to offer medical screening to former workers and their household contacts at selected vermiculite sites across the U.S., including this site in Minneapolis, Minnesota. ATSDR also worked with MDH and University of Minnesota to conduct medical screening of a community cohort. Results of the medical screening efforts will be published in a separate report(s).

Lead public health agency for health consultation: Minnesota Department of Health

ATSDR/EPA Region 5

The Scotts Company, LLC (Formerly O.M. Scott & Sons Company)
14111 Scottslawn Road
Marysville, Union County, Ohio

Type of facility: Agricultural products manufacturing (exfoliated vermiculite at the site in the past)
Estimated timeframe for processing VC from Libby: 1963–1980
Estimated amount of VC received from Libby, Montana: 429,500 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1980.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 185
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: The 830 acre facility is located in a sparsely populated rural area. The nearest residential area is 1/2 mile west of the site. The site currently is used for industrial and commercial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
O.M Scott and Sons Company	1972–1976*	Personal and area (engineering) samples
National Institute for Occupational Safety and Health	2000	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
O.M Scott and Sons Company	2000	Soil
National Institute for Occupational Safety and Health	2000	Indoor air
EPA Region 5	2000	Soil

Remediation (cleanup) conducted at the site? No

Note: ATSDR is working with external partners to conduct a study of disease progression in employees from this facility who were exposed to asbestos-containing vermiculite in the past. ATSDR is also conducting an investigation of disease prevalence among household contacts of these vermiculite workers. Results of these efforts will be published in a separate report.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 6

Former Zonolite Company/W.R. Grace & Company
4729 River Road
New Orleans, Jefferson Parish, Louisiana

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1965–1989
Estimated amount of VC received from Libby, Montana: 148,300 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1988.)
Approximate number of employees at a given time (during vermiculite processing): 8–12
Population within a 1-mile radius of the site in 1990: 5,047
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2 acre site is residential, commercial, and industrial. The nearest residential area is a few hundred yards east and northeast of the site. The site was used for commercial and light industrial operations unrelated to vermiculite exfoliation prior to 2005. The status of the site after Hurricane Katrina in 2005 is unknown.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1975–1988*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1989	Indoor air (after plant closure)

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	1989	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 6

Former W.R. Grace & Company/Texas Vermiculite
2651 Manila Road
Dallas, Dallas County, Texas

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1953–1992
Estimated amount of VC received from Libby, Montana: 396,900 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1993.)
Approximate number of employees at a given time (during vermiculite processing): 16–42
Population within a 1-mile radius of the site in 1990: 7,140
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 5.7 acre site is commercial, industrial, and residential. The nearest residential area is 1/4 mile north of the site. The site remained unused after 1992 when vermiculite operations ceased. W.R. Grace demolished the buildings on the site in 2001.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1972–1991*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1997	Indoor air (after plant closure)
EPA Region 6	2001	Soil, indoor dust, bulk material from inside the former processing building

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	1996–1997	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
W.R. Grace	2001	W.R. Grace hired asbestos contractors to conduct an inspection of the site, perform asbestos abatement, demolish the structures on the site, and grade and seed the area where the buildings stood.

Note: Parkland Memorial Hospital and University of Texas Health Center in Tyler shared a $250,000 state grant to provide medical screening to eligible community members associated with this former vermiculite processing facility. ATSDR and Texas Department of State Health Services provided some consulting and technical support during the planning stage of the medical screening project.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 7
Former Zonolite/W.R. Grace & Company
1705 Sulphur Avenue
St. Louis, Missouri

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1944–1988
Estimated amount of VC received from Libby, Montana: 139,500 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1988.)
Approximate number of employees at a given time (during vermiculite processing): 12–19
Population within a 1-mile radius of the site in 1990: 13,609
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 1.5 acre site is primarily industrial and residential. The nearest residential area is about 1/10 mile north and northwest of the site. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976–1986*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1990	Indoor air (after plant closure)
EPA Region 7	2000	Soil

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	1990	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: Missouri Department of Health and Senior Services

ATSDR/EPA Region 7
Former Western Mineral Products
3520 I Street
Omaha, Douglas County, Nebraska

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1940s–1989
Estimated amount of VC received from Libby, Montana: 166,500 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1991.)
Approximate number of employees at a given time (during vermiculite processing): 5–24
Population within a 1-mile radius of the site in 1990: 121
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the site is primarily commercial and industrial. The nearest residential area is 1/4 mile northwest and southeast of the site. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1976, 1986*	Personal samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1991	Indoor air (after plant closure)
EPA Region 7	2000	Soil

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 8
Former Western Mineral Products
111 South Navajo Street
Denver, Denver County, Colorado

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1950–1990
Estimated amount of VC received from Libby, Montana: 103,000 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1988.)
Approximate number of employees at a given time (during vermiculite processing): 4–11
Population within a 1-mile radius of the site in 1990: 12,822
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2 acre site is primarily light industrial and residential. The nearest residential area is 1/4 mile east of the site. A community ball field is located across the street from the site. The site currently is being used for industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1975–1981*	Personal samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1990	Indoor air (after plant closure)
EPA Region 8	2001	Soil, indoor air from the exfoliation building Soil, indoor air from adjacent properties
EPA Region 8	2003	Soil

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	Unknown	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
EPA Region 8	2003	Excavated 450 cubic yards of contaminated soil from the site and adjacent right-of-way areas, excavated 2,100 cubic yards of contaminated soil at the city park.
Burlington-Northern Santa Fe Railroad	2005–2006	Excavated 5,800 tons of contaminated soil from rail areas. EPA approved the work plan and provided oversight during field activities.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 8
Former Robinson Insulation
826 4th Avenue
Minot, Ward County, North Dakota

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1945–1983
Estimated amount of VC received from Libby, Montana: 16,200 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1983.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 9,484
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the site is commercial, industrial, and residential. Residential properties were located across the street from the site in the past. Now, the nearest residential area is 175 yards south of the site. The site currently is being used by the Minot City Parks Department.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 8	2001–2002	Soil, indoor dust from the two exfoliation buildings, personal samples (air) during collection of environmental samples. Soil from adjacent streets, residences, and businesses; indoor dust from abandoned residence across the street from the site.

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
EPA Region 8	2002	Demolished and removed the two former exfoliation buildings and the abandoned house across the street, excavated and removed contaminated soil at the site.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 9

Former Ari-Zonolite
6960 North 52nd Avenue
Glendale, Maricopa County, Arizona

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1951–1964
Estimated amount of VC received from Libby, Montana: Unknown
(Invoices from W.R. Grace & Company were not available for this facility.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 16,642
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the site is primarily commercial and residential. After vermiculite processing ceased in 1964, a number of different businesses unrelated to vermiculite exfoliation used the site. The last known occupant was an automotive restoration business that vacated the site in 2002.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 9	2001	Soil, indoor dust from the exfoliation building, indoor air from the exfoliation building

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
Site owner	2001	Removal of indoor asbestos-containing dust (based on EPA Region 9 sampling results).

Note: ATSDR collaborated with state health departments to offer medical screening to former workers and their household contacts at selected vermiculite sites across the U.S., including the Glendale, Arizona, site. Results of the medical screening will be published in a separate report.

Lead public health agency for health consultation: Arizona Department of Health Services

ATSDR/EPA Region 9
W.R. Grace & Company
4220 West Glenrosa Avenue
Phoenix, Maricopa County, Arizona

Type of facility: Current vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1964–1992
Estimated amount of VC received from Libby, Montana: 254,900 tons
(Source: Available invoices from W.R. Grace & Company during 1969–1992.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 12,915
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2 acre site is primarily commercial and residential. The nearest residential areas are 1/2 mile northeast and southwest of the site. The site currently exfoliates vermiculite obtained from a mine in South Carolina.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1972–1988*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 9	2001	Soil, indoor dust from the exfoliation building, indoor air from the exfoliation building, bulk material

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	2001	Excavated contaminated soil from the rail loading area, cleaned indoor horizontal surfaces where asbestos-containing dust was detected. EPA Region 9 provided oversight during the cleanup actions.

Note: ATSDR collaborated with state health departments to offer medical screening to former workers and their household contacts at selected vermiculite sites across the U.S., including the Phoenix, Arizona, site. Results of the medical screening will be published in a separate report.

Lead public health agency for health consultation: Arizona Department of Health Services

ATSDR/EPA Region 9

Former California Zonolite/W.R. Grace & Company
5440 West San Fernando Road
Glendale, Los Angeles County, California

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1950–1977
Estimated amount of VC received from Libby, Montana: 120,200 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1979.)
Approximate number of employees at a given time (during vermiculite processing): 19
Population within a 1-mile radius of the site in 1990: 1,748
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 2.75 acre site is commercial, light industrial, and residential. The nearest residential area is 500 yards east of the site. The site currently is being used for industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1972–1977*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 9	2001	Soil, indoor dust from the exfoliation building, indoor air from the exfoliation building, bulk material

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
Site owners	2002	Excavated contaminated soil, cleaned indoor areas where asbestos-containing dust was detected. EPA Region 9 provided oversight during the cleanup actions.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 9
Former W.R. Grace & Company
6851 Smith Avenue
Newark, Alameda County, California

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1966–1993
Estimated amount of VC received from Libby, Montana: 337,100 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1992.)
Approximate number of employees at a given time (during vermiculite processing): 18–30
Population within a 1-mile radius of the site in 1990: 10,183
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the site is commercial, industrial, and residential. The site currently is being used for light industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1975–1988*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1994	Indoor air (after plant closure)
EPA Region 9	2001	Soil, indoor dust from the exfoliation building, indoor air from the exfoliation building, bulk material

Remediation (cleanup) conducted at the site? W.R. Grace reportedly cleaned the facility after vermiculite exfoliation operations ceased.

Conducted by	Date	Type of cleanup
W.R. Grace	1994	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
Site owner	2002	Excavated contaminated soil, cleaned indoor areas where asbestos-containing dust was detected. EPA Region 9 provided oversight during the cleanup actions.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 9
W.R. Grace & Company
2502 South Garnsey Street
Santa Ana, Orange County, California

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1971–1993
Estimated amount of VC received from Libby, Montana: 453,000 tons
(Source: Available invoices from W.R. Grace & Company during 1971–1988.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 35,832
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 4 acre site is primarily light industrial, commercial, and residential. The site is still owned by W.R. Grace and is used for industrial operations unrelated to vermiculite exfoliation.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1975–1987*	Personal and area (engineering) samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 9	2001	Soil, indoor dust from former exfoliation areas, indoor air from former exfoliation areas

Remediation (cleanup) conducted at the site? No

Note: ATSDR collaborated with state health departments to offer medical screening to former workers and their household contacts at selected vermiculite sites across the U.S., including the Santa Ana, California, site. Results of the medical screening will be published in a separate report.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 9
Former Vermiculite of Hawaii
842-A Mapunapuna Street
Honolulu, Honolulu County, Hawaii

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1954–1983
Estimated amount of VC received from Libby, Montana: 6,000 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1983.)
Approximate number of employees at a given time (during vermiculite processing): Unknown
Population within a 1-mile radius of the site in 1990: 23,317
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 0.8 acre site is primarily commercial and industrial. The nearest residential properties are in a military housing area a few hundred yards west of the site. Other businesses, unrelated to vermiculite exfoliation, have operated at the site since vermiculite processing ceased in 1983.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 9	2001	Soil, indoor dust from former exfoliation areas, indoor air from former exfoliation areas, bulk material

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
Site owner	2001	Excavated contaminated soil, cleaned indoor areas where asbestos-containing dust and other materials were detected. EPA Region 9 provided oversight during the cleanup actions.

Lead public health agency for health consultation: Agency for Toxic Substances and Disease Registry

ATSDR/EPA Region 10

Former Vermiculite Northwest, Inc./ W.R. Grace & Company
2302 North Harding Avenue
Portland, Multnomah County, Oregon

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: early 1950s–1993
Estimated amount of VC received from Libby, Montana: 198,500 tons
(Source: Available invoices from W.R. Grace & Company during 1967–1991.)
Approximate number of employees at a given time (during vermiculite processing): 13–21
Population within a 1-mile radius of the site in 1990: 8,316
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the site is primarily industrial. The nearest residential area is 1/4 mile northeast of the site. Parts of the site were leased by W.R. Grace to other businesses starting in 1961, while vermiculite exfoliation was occurring at the site. W.R. Grace sold the property in 1994. Since that time, other businesses have leased space and operated in the same building where vermiculite exfoliation was conducted in the past.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1970s*	Personal samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1994	Indoor air (after plant closure)
EPA Region 10	2001	Soil, indoor dust, indoor air, bulk material
EPA Region 10	2005	Soil, indoor air, bulk material

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
W.R. Grace	1994	Company procedure for plant close-out specifies (1) vacuum and water rinse of equipment, walls and floors and (2) equipment removal.
W.R. Grace	2001	Removed contaminated dust and other asbestos-contaminated materials found inside the buildings. Oregon Department of Environmental Quality provided oversight during the cleanup.
Site owner	2006	Excavated contaminated soil, removed contaminated material from indoor crawl spaces and other areas.

Lead public health agency for health consultation: Oregon Department of Human Services

ATSDR/EPA Region 10
Supreme Perlite
4600 North Suttle Road
Portland, Multnomah County, Oregon

Type of facility: Perlite exfoliation, also exfoliated vermiculite in the past
Estimated timeframe for processing VC from Libby: 1968–1974
Estimated amount of VC received from Libby, Montana: 700 tons
(Source: Available invoices from W.R. Grace & Company during 1971–1974.)
Approximate number of employees at a given time (during vermiculite processing): 3–6
Population within a 1-mile radius of the site in 1990: 139
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: Land use surrounding the 3 acre site is primarily industrial or undeveloped. The nearest residences are houseboats on the Columbia River, approximately ¼ mile northeast of the site. The closest residential areas are over 1 mile northeast of the site. The site currently is being used for perlite exfoliation.

Occupational sampling conducted at the site? Unknown

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 10	2000	Soil, indoor dust from former exfoliation areas

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
Site owner	2001	Excavated contaminated soil in the area of the rail spur and unloading area

Lead public health agency for health consultation: Oregon Department of Human Services

ATSDR/EPA Region 10

Former Vermiculite Northwest, Inc.
1318 North Maple Street
Spokane, Spokane County, Washington

Type of facility: Former vermiculite exfoliation
Estimated timeframe for processing VC from Libby: 1940s–1974
Estimated amount of VC received from Libby, Montana: 15,200 tons
(Source: Available invoices from W.R. Grace & Company during 1966–1974.)
Approximate number of employees at a given time (during vermiculite processing): 21
Population within a 1-mile radius of the site in 1990: 17,214
(Source: 1990 U.S. Census data processed using area-proportion spatial analysis techniques.)

Current land/site use: In 2007, the site was covered with an asphalt cap. This work was done under the Washington State Department of Ecology Voluntary Cleanup Program. Land use surrounding the 1.5 acre site is primarily commercial and residential. The nearest residential areas are about 30 feet south and 320 feet north of the site. The site currently is owned by Spokane County.

Occupational sampling conducted at the site? Yes

Conducted by	Date	Sample Type
W.R. Grace	1970s*	Personal samples

* This is an estimate is based on data available to ATSDR.

Environmental sampling conducted at the site? Yes

Conducted by	Date	Sample Type
EPA Region 10	2000	Soil, indoor dust from the site Soil from adjacent properties
EPA Region 10	2001	Soil samples
EPA Region 10	2002	Soil, air samples collected during disturbance activities (activity-based sampling)

Remediation (cleanup) conducted at the site? Yes

Conducted by	Date	Type of cleanup
Spokane County	2002	Demolished the buildings, removed some contaminated soil, agreed to clean up remainder of contaminated soil through the state voluntary cleanup program when site redevelopment plans are finalized.

Lead public health agency for health consultation: Washington State Department of Health

Appendix C. Historical personal and area sampling data from W.R. Grace vermiculite exfoliation facilities

Personal and area sampling data were available from industrial hygiene monitoring conducted by W.R. Grace at a number of its vermiculite exfoliation facilities. ATSDR obtained the W.R. Grace monitoring information from Remedium Group, Inc., a subsidiary of W.R. Grace, and from the database of W.R. Grace documents that EPA Region 8 obtained during the EPA investigation of the Libby mine. For this report, ATSDR analyzed the W.R. Grace exposure data as reported, because it is often the only exposure data available for former workers at the exfoliation sites. ATSDR cannot verify the accuracy of the data or the manner in which W.R. Grace conducted its occupational exposure sampling and analysis.

W.R. Grace may have initiated the industrial hygiene monitoring for asbestos in 1969 in conjunction with a dust control program described in company documents (EPA, unpublished data, 2000).[2] W.R. Grace company records also indicate a fiber reduction program was implemented in 1976 in response to high fiber concentrations measured at some of the company's exfoliation plants (EPA, unpublished data, 2000).

W.R. Grace industrial hygienists collected personal samples from employees in various job categories, including shift supervisors, furnace operators, product baggers, forklift drivers, and maintenance personnel. Most of the area sampling was conducted at locations in the exfoliation process where asbestos was likely to be released (e.g., the furnace baghouse, the furnace stoner deck where waste rock and expanded product were separated, the waste rock hopper) (EPA, unpublished data, 2000). Some area samples were also collected in common areas such as offices and employee lunchrooms.

Industrial hygiene sample sheets, which included sampling location, sampling time, and laboratory analysis results, were available for some of the samples. These sample sheets indicate that sample collection times varied from 15 minutes to several hours. Other sampling data were reported in internal company memoranda as time-weighted averages, without accompanying sample collection or analysis details.

The samples collected by W.R. Grace industrial hygienists were analyzed by an internal, W.R. Grace laboratory. A company document from 1979 entitled "Procedure for fiber counting" instructs that fibers greater than 5 micrometers (μm) in length with an aspect ratio (ratio of length to width) of greater than 3 should be counted (EPA, unpublished data, 2000). The document also states that fibers with diameter greater than 3 μm should not be counted. The "Procedure for fiber counting" document describes sample slide preparation and microscope setup procedures that suggest light microscopic (PCM) techniques were used for sample analysis.

ATSDR aggregated the personal and area sampling results that were available for 17 different exfoliation facilities (Figures C-1 and C-2). These data were available for 1972–1992. Summary statistics for each of the 17 different exfoliation facilities are included in Tables C-1 and C-2. ATSDR used the detection limit (if it was documented) as proxy for sample results reported as non-detect. The data represent short duration sample collection. The median sample collection

[2] W.R. Grace company documents that EPA Region 8 obtained during the Libby mine investigation. This database of documents contains confidential business information and private information that is not publicly available.

time for the personal sample data was 40 minutes (collection time ranged from 10 minutes to 7 hours). The median sample collection time for the area samples was 50 minutes (collection time ranged from 8 minutes to 4 hours). In this setting, short duration air samples seemed to be necessary to prevent the sample collection filter from becoming overloaded with fibers and dust. If a sample filter is overloaded, it cannot be properly analyzed.

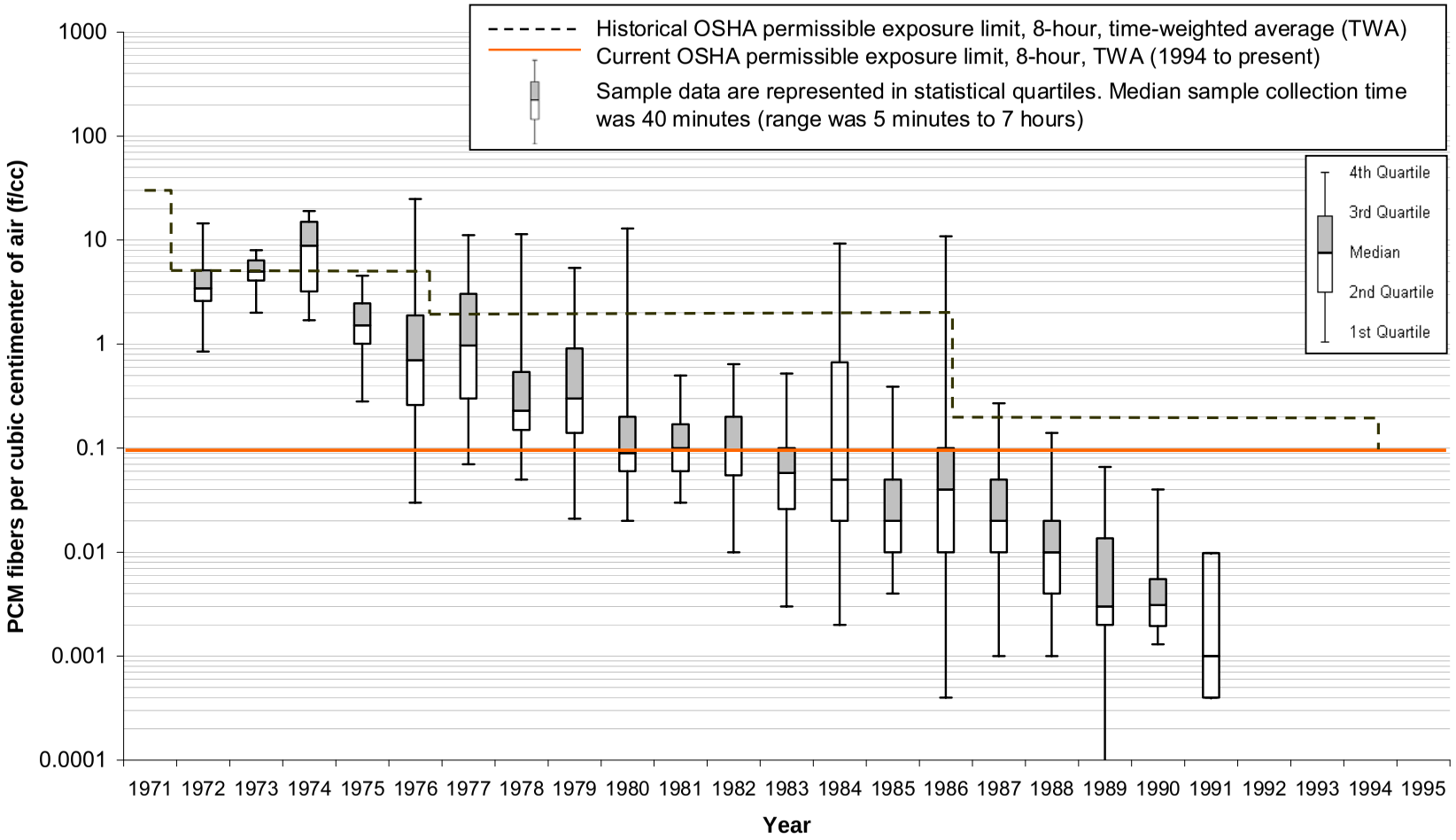
The data were aggregated across the 17 sites because sampling data for each of the sites were generally similar in magnitude for the same time periods, and they demonstrated the same trend of decreasing measured fiber levels throughout the 1970s and 1980s. Similarly, personal data were aggregated across various job categories. Although several distinct job categories existed (such as furnace operator, bagger, forklift driver), all of the work involved direct contact with or close proximity to VC and waste rock during transport, handling, and physical processing. Also, industrial hygiene data sheets indicate workers did not always have the same job assignments from day to day. These were not highly specialized jobs; therefore, employees could have performed different job assignments as needed.

Current and historical levels of the OSHA permissible exposure limit (PEL) are included in Figures C-1 and C-2. The OSHA permissible exposure level (PEL) for airborne asbestos is the 8-hour time-weighted average representing the limit of exposure for a worker during a normal work day. Typically, short duration sample results are not directly compared to the OSHA PEL because they do not necessarily represent exposure over an entire 8-hour work shift. This is particularly true if work tasks vary throughout the day. However, on the basis of field observations of two active vermiculite exfoliation facilities and historical records from numerous others, employee job tasks at these facilities were consistent throughout the workday. A comparison of available short-duration sampling results and time-weighted average sampling results for a former exfoliation facility in Dallas, Texas, suggests that these measures are similar in the vermiculite exfoliation plant settings studied (Figure C-3).

The OSHA PEL has been lowered several times since it was introduced in 1971: 12 f/cc (initial level, May 1971), 5 f/cc (December 1971), 2 f/cc (July 1976), 0.2 f/cc (June 1986), and 0.1 f/cc (August 1994).[3] Currently, the OSHA PEL stands at 0.1 f/cc. However, OSHA's final rules for occupational exposure to asbestos acknowledge that "…a significant risk remains at the PEL of 0.1 f/cc."[4] Instead of reducing the PEL any further in 1994, OSHA elected to promote the reduction or elimination of risk through mandated work practices, including engineering controls and respiratory protection for various classifications of asbestos-related construction and maintenance activities.

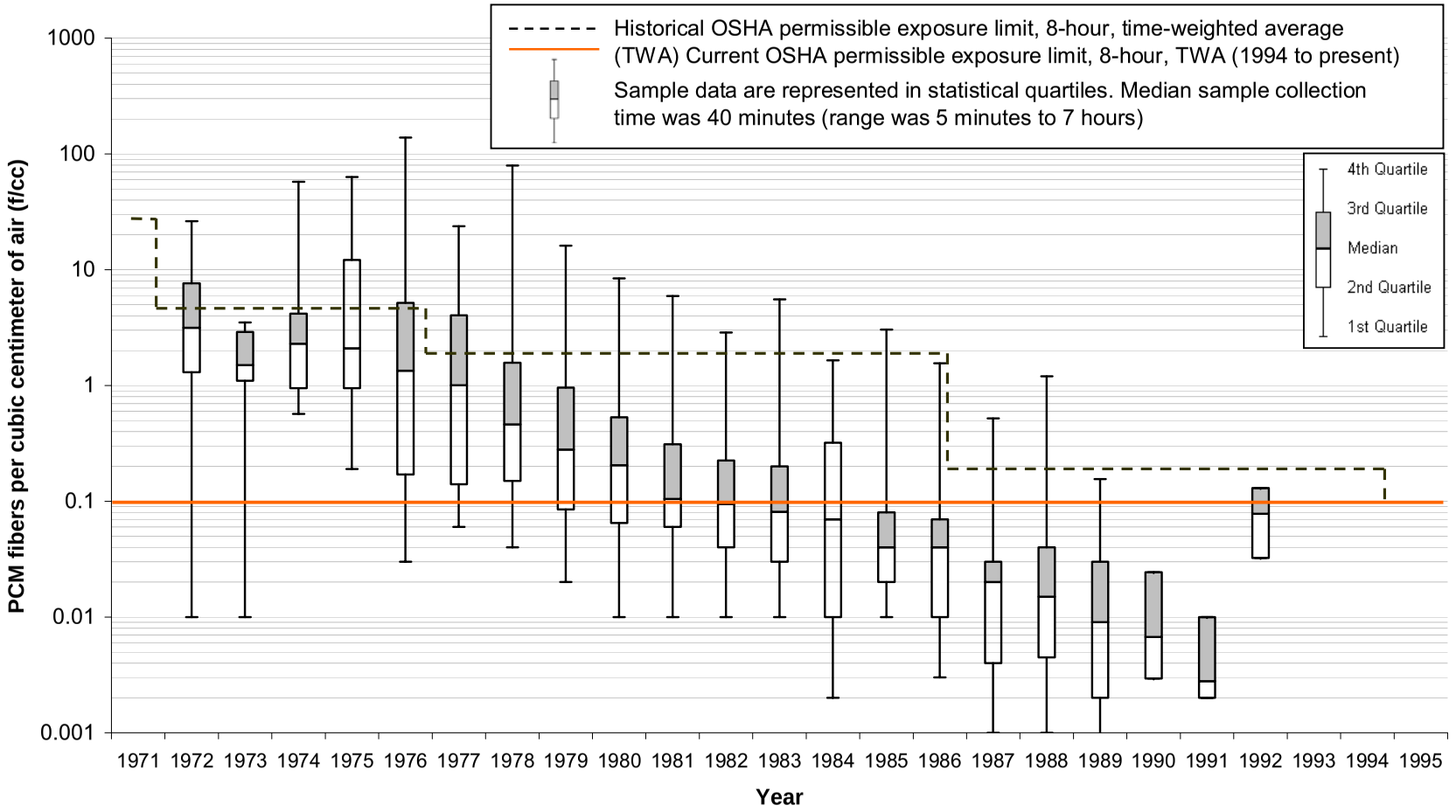
[3] Occupational Safety and Health Administration: Introduction to 29 CFR Parts 1910, 1915, 1926, occupational exposure to asbestos. Federal Register 1994 August 10;59:40964-41162.
[4] Ibid.

Figure C-1. Airborne phase contrast microscopy (PCM) fiber concentrations over time: personal sample data (N=1,901) from 17 W.R. Grace vermiculite exfoliation facilities



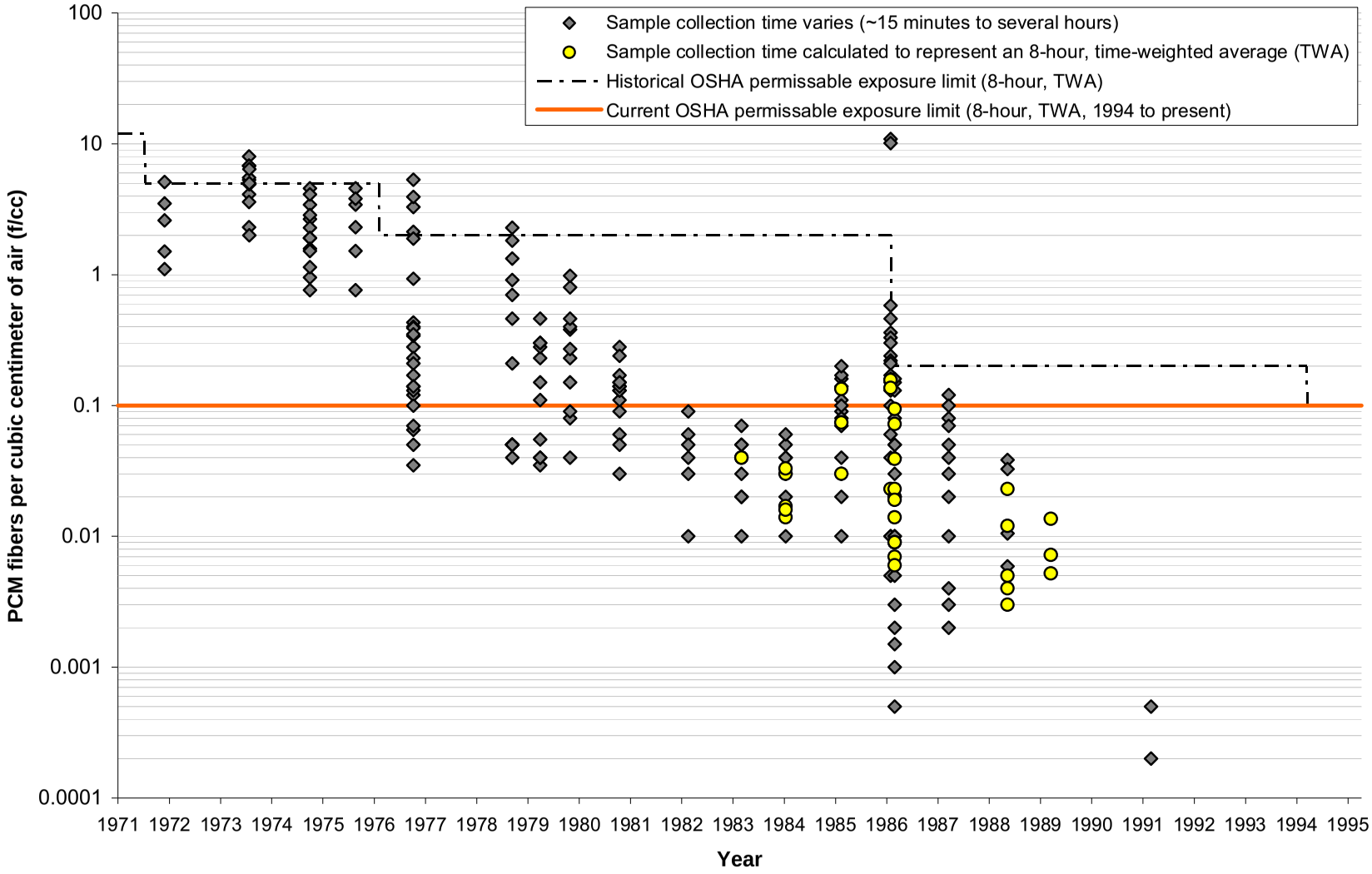
Source: W.R. Grace Industrial Hygiene Surveys, 1972–1991. Personal samples were collected within a worker's breathing zone. Fiber concentrations were determined by phase contrast microscopy (PCM) using counting rules defined by W.R. Grace (similar to NIOSH Method 7400).

Figure C-2. Airborne phase contrast microscopy (PCM) fiber concentrations over time: area sample data (N=902) from 17 W.R. Grace vermiculite exfoliation facilities



Source: W.R. Grace Industrial Hygiene Surveys, 1972–1991. Area samples were collected at various points around the processing equipment or other occupied spaces of the building. Fiber concentrations were determined by phase contrast microscopy (PCM) using counting rules defined by W.R. Grace (similar to NIOSH Method 7400).

Figure C-3. Airborne phase contrast microscopy (PCM) fiber concentrations over time: personal sample data (N=286) at the Texas Vermiculite/W.R. Grace Dallas facility, Dallas, Texas



Source: W.R. Grace Industrial Hygiene Surveys, 1972–1991. Personal samples were collected within a worker's breathing zone. Fiber concentrations were determined by phase contrast microscopy (PCM) using counting rules defined by W.R. Grace (similar to NIOSH Method 7400)

Table C-1. Summary statistics for personal sample data (N=1,901) from 17 W.R. Grace vermiculite exfoliation facilities

Facility	Year	Number of samples	Measured fiber concentration (f/cc)		
			Minimum	Median	Maximum
Beltsville, MD	1976	10	0.27	1.495	5.7
	1977	29	0.21	1.52	6.34
	1978	12	0.05	0.13	0.71
	1979	8	0.021	0.29	0.39
	1980	18	0.02	0.09	12.91
	1981	8	0.04	0.06	0.17
	1982	9	0.09	0.13	0.36
	1983	9	0.003	0.027	0.081
	1984	6	0.01	0.03	0.05
	1985	13	0.004	0.02	0.1
	1986	16	0.003	0.045	0.18
	1987	11	0.001	0.01	0.09
	1988	9	0.01	0.02	0.03
	1989	2	0.038	0.0385	0.039
Dallas, TX	1972	6	1.1	2.05	5.1
	1973	15	2	5	8
	1975	15	0.76	1.9	4.56
	1976	6	0.76	2.86	4.56
	1977	26	0.07	0.255	5.32
	1979	36	0.07	0.15	2.28
	1980	12	0.08	0.25	0.98
	1981	15	0.05	0.13	0.28
	1982	8	0.01	0.045	0.09
	1983	9	0.01	0.03	0.07
	1984	25	0.01	0.02	0.06
	1985	15	0.01	0.08	0.2
	1986	61	0.001	0.04	10.89
	1987	32	0.002	0.01	0.12
	1989	4	0.00001	0.0062	0.0136
	1991	2	0.0004	0.0007	0.001
Dearborn, MI	1986	39	0.004	0.03	0.36
	1988	24	0.001	0.01	0.14
	1989	15	0.001	0.016	0.066
Easthampton, MA	1974	2	1.7	2.65	3.6
	1976	7	0.32	0.63	3.04
	1977	26	0.08	2.83	6.59
	1978	26	0.08	0.285	0.96
	1979	11	0.14	0.43	0.95
	1980	16	0.08	0.205	1.37
	1983	7	0.003	0.064	0.111
	1984	34	0.003	1.055	9.29
	1985	14	0.01	0.01	0.02
	1986	22	0.003	0.0075	0.05
	1987	12	0.001	0.0145	0.034
	1988	32	0.001	0.004	0.028
	1989	10	0.001	0.0025	0.003
	1990	16	0.0013	0.0031	0.04
	1991	1	0.0098	0.0098	0.0098
Glendale (LA), CA	1972	8	3.14	6.345	14.48
	1976	15	0.04	0.57	3.8
	1977	9	0.3	1.39	2.63
Hamilton	1976	25	0.08	0.59	24.9
Township, NJ	1977	11	0.1	0.4	0.76
	1978	10	0.08	0.395	0.81
	1980	15	0.03	0.06	0.17
	1981	12	0.04	0.08	0.4
	1982	13	0.03	0.05	0.17
	1986	15	0.02	0.04	0.12
New Castle, PA	1976	15	1.2	2.2	5.7
	1982	15	0.02	0.08	0.21
	1988	27	0.002	0.02	0.1

Table C-1, continued. Summary statistics for personal sample data (N=1,901) from 17 W.R. Grace vermiculite exfoliation facilities

Facility	Year	Number of samples	Measured fiber concentration (f/cc)		
			Minimum	Median	Maximum
Minneapolis, MN	1974	9	2.22	9.5	19
	1976	17	0.11	1.89	3.42
	1978	23	0.11	0.23	11.4
	1979	6	0.06	0.15	0.17
	1980	12	0.04	0.09	0.2
	1983	7	0.01	0.16	0.52
	1984	4	0.07	0.205	0.33
	1985	18	0.007	0.03	0.39
	1986	67	0.004	0.07	0.91
	1987	18	0.002	0.015	0.09
	1988	19	0.01	0.02	0.05
New Orleans, LA	1975	3	0.28	0.57	1.06
	1976	8	0.2	0.46	0.86
	1978	9	0.19	0.72	1.06
	1980	5	0.06	0.23	0.68
	1981	8	0.04	0.09	0.23
	1983	8	0.016	0.038	0.059
	1987	28	0.001	0.02	0.17
	1988	11	0.01	0.04	0.07
Newark, CA	1975	8	0.29	1.165	2.09
	1976	27	0.03	0.14	3.65
	1977	15	0.96	4.1	11.15
	1979	20	0.61	1.59	5.42
	1987	18	0.002	0.02	0.15
Phoenix, AZ	1972	4	0.85	2.85	4.5
	1976	4	0.15	0.835	4.56
	1985	11	0.004	0.03	0.31
	1986	23	0.001	0.02	0.21
	1987	46	0.002	0.02	0.19
	1988	7	0.001	0.004	0.01
Santa Ana, CA	1975	18	0.57	1.71	3.04
	1976	5	0.06	0.1	1.39
	1977	11	0.18	0.3	2.13
	1978	10	0.13	0.3	1.27
	1980	16	0.03	0.135	0.5
	1981	20	0.03	0.085	0.46
	1983	3	0.06	0.07	0.1
	1987	24	0.002	0.02	0.15
St. Louis, MO	1978	7	0.2	0.46	0.91
	1980	12	0.02	0.05	0.09
Tampa, FL	1976	8	0.11	0.34	0.48
West Chicago, IL	1986	54	0.0004	0.03	0.9
	1987	36	0.001	0.03	0.27
Weedsport, NY	1982	18	0.07	0.3	0.64
	1984	8	0.002	0.01	0.01
Wilder, KY	1976	18	0.28	1.615	5.47
	1978	24	0.13	0.15	0.26
	1981	16	0.04	0.15	0.5
	1982	9	0.02	0.12	0.46
	1983	10	0.07	0.145	0.3
	1986	90	0.003	0.08	0.46
	1987	36	0.003	0.04	0.21
	1988	23	0.002	0.01	0.1
	1989	11	0.001	0.003	0.01

Table C-2. Summary statistics for area sample data (N=902) from 17 W.R. Grace vermiculite exfoliation facilities

Facility	Year	Number of samples	Measured fiber concentration (f/cc)		
			Minimum	Median	Maximum
Beltsville, MD	1977	13	0.2	1.52	9.42
	1978	4	0.15	0.15	0.3
	1979	8	0.1	0.27	0.79
	1980	12	0.03	0.165	0.66
	1981	8	0.01	0.055	0.31
	1982	10	0.02	0.125	0.59
	1983	9	0.04	0.2	5.54
	1984	4	0.05	0.075	0.75
	1985	10	0.01	0.03	0.08
	1986	4	0.005	0.105	0.32
	1987	7	0.01	0.04	0.52
	1988	6	0.01	0.175	1.2
	1989	13	0.002	0.03	0.113
	1990	4	0.0097	0.02435	0.8087
Dallas, TX	1972	1	5.1	5.1	5.1
	1973	7	0.01	1.5	3.5
	1975	1	37.62	37.62	37.62
	1976	8	1.1	3.93	14.8
	1977	1	0.06	0.06	0.06
	1979	15	0.07	0.23	0.88
	1980	8	0.04	0.21	0.98
	1981	10	0.06	0.2	2.23
	1982	10	0.01	0.085	0.23
	1983	12	0.01	0.025	0.19
	1984	4	0.002	0.0065	0.01
	1985	8	0.03	0.22	3.04
	1986	12	0.003	0.04	0.1
	1987	4	0.001	0.0025	0.01
	1988	6	0.001	0.003	0.0081
	1989	2	0.002	0.0025	0.003
	1991	4	0.0015	0.00185	0.0028
Dearborn, MI	1986	4	0.02	0.045	0.22
	1988	9	0.004	0.06	0.13
Dearborn, MI	1989	12	0.006	0.0595	0.156
Easthampton, MA	1974	7	0.57	1.3	3.8
	1976	4	0.52	7.765	139
	1977	14	0.09	0.47	8.82
	1978	1	0.09	0.09	0.09
	1979	6	0.91	1.785	2.17
	1980	18	0.01	0.57	4.76
	1983	8	0.038	0.083	0.754
	1984	13	0.01	0.07	0.81
	1985	5	0.01	0.02	0.02
	1986	7	0.006	0.007	0.018
	1987	5	0.003	0.003	0.005
	1988	10	0.003	0.0075	0.03
	1989	14	0	0.002	0.004
	1991	3	0.0028	0.0495	0.097
Glendale (LA), CA	1976	9	0.08	0.46	16.57
	1977	3	0.08	0.08	0.57
Hamilton	1976	1	0.27	0.27	0.27
Township, NJ	1977	6	0.06	0.565	2.6
	1978	5	0.18	0.73	28.81
	1979	8	0.02	0.09	1.1
	1980	14	0.05	0.095	3.27
	1981	8	0.05	0.105	4.92
	1982	10	0.02	0.07	2.87
	1983	16	0.02	0.27	1.71
	1986	8	0.02	0.06	0.28

Table C-2, continued. Summary statistics for area sample data (N=902) from 17 W.R. Grace vermiculite exfoliation facilities

Facility	Year	Number of samples	Measured fiber concentration (f/cc)		
			Minimum	Median	Maximum
Minneapolis, MN	1972	11	0.01	3.7	15.2
	1974	3	4.18	9.5	57.57
	1976	2	2.68	11.645	20.61
	1978	23	0.07	0.9	13.53
	1979	5	0.06	0.14	0.35
	1980	6	0.02	0.045	0.14
	1981	9	0.05	0.09	1
	1982	10	0.02	0.185	1.98
	1983	3	0.1	0.11	0.38
	1984	3	0.01	0.08	1.65
	1985	11	0.01	0.06	0.34
	1986	15	0.01	0.06	0.14
	1987	6	0.01	0.015	0.03
	1988	5	0.001	0.01	0.03
	1989	5	0.0004	0.0012	0.0091
New Castle, PA	1972	12	0.6	2.5	26.2
New Orleans, LA	1976	3	4.8	5.07	22.8
	1982	7	0.03	0.07	1.62
	1984	4	0.05	0.115	0.74
	1986	8	0.004	0.025	0.12
	1988	16	0.01	0.03	0.09
	1975	2	0.28	0.71	1.14
	1976	4	0.05	0.125	0.68
	1978	4	0.3	0.515	1.28
	1981	7	0.01	0.33	5.93

Facility	Year	Number of samples	Measured fiber concentration (f/cc)		
			Minimum	Median	Maximum
Newark, CA	1983	8	0.01	0.03	0.15
	1985	5	0.02	0.04	0.06
	1986	4	0.01	0.015	0.02
	1987	4	0.001	0.002	0.01
	1988	4	0.001	0.001	0.004
Phoenix, AZ	1975	3	0.19	0.38	0.76
	1976	17	0.03	1.34	11.25
	1977	6	1.82	6.23	23.71
	1979	7	0.27	4.1	16.17
Santa Ana, CA	1987	10	0.001	0.0065	0.02
	1976	9	0.05	1.82	13.96
	1979	7	0.07	0.76	1.37
	1982	9	0.02	0.06	0.91
	1987	10	0.01	0.025	0.05
	1975	10	1.14	7.22	63.18
	1977	3	0.14	0.15	9.12
St. Louis, MO	1978	8	0.04	0.325	79.13
Tampa, FL	1979	8	0.08	0.085	4.86
West Chicago, IL	1986	26	0.01	0.05	1.56
	1987	10	0.02	0.03	0.2
	1991	3	0.001	0.002	0.003
Weedsport, NY	1982	8	0.01	0.08	0.31
	1984	3	0.002	0.01	0.14
Wilder, KY	1986	8	0.003	0.015	0.04
	1988	8	0.002	0.01	0.02
	1989	10	0.002	0.0095	0.01
	1990	4	0.002	0.00295	0.0038
	1992	4	0.0313	0.07825	0.138
	1976	1	0.27	0.27	0.27