Health Consultation

W.R. GRACE & COMPANY SITE

202 EAST CHERRY STREET

NEW CASTLE, LAWRENCE COUNTY, PENNSYLVANIA

SEPTEMBER 22, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
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Foreword: ATSDR's National Asbestos Exposure Review

Vermiculite, a naturally occurring mineral, was mined and processed in Libby, Montana, from the early 1920s until 1990. We now know that this vermiculite, which was shipped to many locations in the U.S. for processing, contained asbestos.

The National Asbestos Exposure Review (NAER) is a project of the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is working with other federal, state, and local environmental and public health agencies to evaluate public health impacts at sites that processed Libby vermiculite.

The evaluations focus on the processing sites and on human health effects that might be associated with possible past, current, or future exposure to asbestos from processing operations. Determining the extent and the hazard potential of commercial or consumer use of products such as vermiculite attic insulation or vermiculite gardening products made with contaminated vermiculite is outside the scope of this project. Information for consumers of vermiculite products has been developed by the U.S. Environmental Protection Agency (EPA), ATSDR, and the National Institute for Occupational Safety and Health (NIOSH). This information is available at www.epa.gov/asbestos/insulation.html.

The sites that processed Libby vermiculite will be evaluated by (1) identifying ways people could have been exposed to asbestos in the past and ways that people could be exposed now and (2) determining whether the exposures represent a public health hazard. ATSDR will use the information gained from the site-specific investigations to recommend further public health actions as needed. Site evaluations are progressing in two phases.

Phase 1: ATSDR has selected 28 sites for the first phase of reviews. These sites were chosen on the basis of the following criteria.

- EPA mandated further action at the site because of contamination in place

- or -

- The site was an exfoliation facility that processed more than 100,000 tons of vermiculite from the Libby mine. Exfoliation, a processing method in which vermiculite is heated and "popped," is expected to have released more asbestos than other processing methods.

The following document is one of the site-specific health consultations ATSDR and its state health partners are developing for each of the 28 Phase 1 sites. A future report will summarize findings at the Phase 1 sites and include recommendations for evaluating the more than 200 remaining sites nationwide that received Libby vermiculite.

Phase 2: ATSDR will continue to evaluate former Libby vermiculite processing sites in accordance with the findings and recommendations contained in the summary report. ATSDR will also identify further actions as necessary to protect public health.

Executive Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the Zonolite/W.R. Grace & Company New Castle site (New Castle facility) because more than 172,000 tons of asbestos-contaminated vermiculite were processed there by exfoliation. Commercial exfoliation of vermiculite is a process of heating uniformly graded pieces of vermiculite in a furnace to expand, or “pop” it into lightweight nuggets.

The New Castle facility operated during 1969–1992. The site, which has not been used since 1992, consists of a 20,000 square-foot building on approximately 2.5 acres of land. In 2004, much of the area outside the building footprint was excavated to remove asbestos-contaminated waste rock used as fill material during facility operations. Land use around the site is a mixture of residential and light commercial. A residential area a few hundred feet to the north of the site was present before the facility began processing vermiculite. Based on U.S. census data, a total of 2,196 people lived within 1 mile of the site in 1990.

Processing and handling of asbestos-contaminated vermiculite and waste rock at the New Castle facility resulted in asbestos exposure to former workers and their household contacts while the facility was operating. Sufficient site-specific and process-specific information is available to consider these exposures a public health hazard. On the basis of available information, ATSDR estimates that from 60 to 120 former workers were exposed during the time the plant operated.

Community members who lived or worked near the New Castle facility in the past could have been exposed to Libby asbestos in a variety of ways. Very little information is available to verify community exposure or to quantify the magnitude, frequency, or duration of such exposure. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached the residential area during 1969–1974 (before the emission control equipment was installed) and (2) stockpiles of waste rock at the site that may have been accessible to community members, especially children. Children who were exposed to asbestos are a population of particular concern because asbestos-related health effects have a long latency period and children who are exposed would have more years to develop problems.

Most community members who live or work near the site now are not being exposed to asbestos from the site. The community exposure pathways that existed while the facility was operating, such as exposure from plant emissions and from contact with piles of vermiculite and waste rock on the site, have been eliminated. In the past, community members or workers may have taken waste rock off the site to use as fill material, driveway surfacing, or as a soil amendment. Not enough information is available to determine whether some individuals may be exposed to Libby asbestos through direct contact with waste rock taken from the site.

Exposure to asbestos does not necessarily mean an individual will get sick. The frequency, duration, and intensity of the exposure, along with personal risk factors such as smoking, history of lung disease, and genetic susceptibility determine the actual risk for an individual. The mineralogy and size of the asbestos fibers involved in the exposure are also important in determining the likelihood and nature of potential health impacts. Because of existing data gaps and limitations in the science related to the type of asbestos at these sites, the risk for current or future health impacts on exposed populations is difficult to quantify.

At this site, where little can be done about past exposure and possible health effects relating to exposure, promoting awareness and offering health education to exposed and potentially exposed populations are important public health actions. Health messages should be structured to facilitate self-identification and to encourage exposed individuals to either inform their primary care physician or consult a physician with expertise in asbestos-related lung disease. Health care provider education would facilitate surveillance and improved recognition of atypical risk factors (for example, those related to nontraditional asbestos-related occupations or nonoccupational exposure) that can contribute to asbestos-related diseases.

Background

ATSDR evaluated the Zonolite/W.R. Grace & Company New Castle site (New Castle facility) because a large amount of vermiculite contaminated with amphibole asbestos was processed at the site by exfoliation. Available invoice data indicate that the facility received approximately 172,000 tons of vermiculite during 1969–1988 (EPA, unpublished data, 2001).[1]

W.R. Grace exfoliated vermiculite at the New Castle facility during 1969–1992 [1] (EPA, unpublished data).[2] The company purchased the site property (approximately 2.5 acres) at 202 East Cherry Street in July 1969 and built the existing 20,000 square foot facility to house exfoliation operations relocated from their Ellwood City, Pennsylvania facility (EPA, unpublished data)[1]. For the first few years of operation, the facility may have been called the Zonolite Company. During facility operations, W.R. Grace used waste rock from exfoliation as fill material in areas south and southeast of the building (EPA, unpublished data)[1]. Fill areas extended onto the property currently owned by CSX Transportation. The New Castle site remained vacant after vermiculite processing ceased in 1992 (EPA, unpublished data)[1].

In the 1990s and early 2000, W.R. Grace conducted a number of site assessment activities, including soil sampling and interior air sampling (EPA, unpublished data)[1]. U.S. Environmental Protection Agency (EPA) Region 3 also completed site investigations in 2000 and 2002 [2, 3]. Based on the findings of these site evaluations, W.R. Grace coordinated with the Pennsylvania Department of Environmental Protection (PADEP) to remediate the site and some of the adjoining CSX property by excavating 7,891 tons of asbestos-contaminated soils in June and July of 2004 [4, 5]. Staff members from PADEP, EPA Region 3, and ATSDR reviewed and approved the Remedial Action Work Plan and Health and Safety Plan developed for the remediation [6, 7].

Table 1. Chronology of site ownership and on-site activities for the New Castle facility

Date	*Site ownership and on-site activities**
1969	W.R. Grace purchased the property (~2.5 acres) and built the vermiculite processing facility.
1992	Vermiculite operations ceased at the site; the building remained unused afterwards.
1994	W.R. Grace hired ENSR to conduct a Phase I environmental site assessment.
1998	W.R. Grace hired Gould Environmental, Inc. to conduct a soil investigation (surface and subsurface soil sampling) at the site.
1999	W.R. Grace hired Gould Environmental, Inc. to collect soil samples in the berm area of the site.
October 2000	EPA Region 3 conducted a preliminary site assessment, including visual site inspection and collection of two bulk samples of material inside the building.
May 2002	EPA conducted a removal assessment at the site, including collection of soil samples from six exterior locations.
September 2003	W.R. Grace hired Gould Environmental, Inc. to delineate contaminated soils at the site and collect air samples inside the building.
June-July 2004	W.R. Grace remediated the site and some of the adjoining CSX property by excavating areas of asbestos-contaminated soil identified in previous sampling efforts.

* Information derived from various sources; references are cited within the text of this report.

[1] Unpublished data from an EPA database of W.R. Grace invoices for shipments of vermiculite from the Libby mine from 1964 through 1990.

[2] Unpublished data from a database of W.R. Grace documents that EPA Region 8 obtained during the Libby mine investigation. This document database contains confidential business information as well as private information that is not available to the public.

In the past, the New Castle facility produced attic insulation, silicone- and asphalt-coated masonry insulation, lightweight concrete aggregate, spray-applied fireproofing for structural steel, and horticultural soil conditioners (EPA, unpublished data). The Monokote 3 (MK-3) fireproofing product was formulated with 10% to 19% chrysotile as an additive; MK-3 production was discontinued at the New Castle facility by July 5, 1973 (EPA, unpublished data). Subsequent formulations of Monokote, MK-4 and MK-5, were produced at the New Castle facility without the addition of chrysotile.

Site description

The New Castle facility is located at 202 East Cherry Street, on the outskirts of the city of New Castle, Lawrence County, Pennsylvania. The site consists of a 20,000 square foot building situated on approximately 2.5 acres of land (Figures 1 and 2). The building has been vacant since exfoliation activities ceased in 1992. Before site remediation in 2004, approximately 75% of the site was covered by the building structure and asphalt or gravel surface cover (EPA, unpublished data). The remainder of the site was covered with grass and trees along the eastern and southern portions of the property. Much of the area outside the building footprint was excavated and backfilled with gravel or clean soil during the recent site remediation effort [5] (Figure 2). There are no fences or other restrictions to limit public access to the site.

The site is bordered to the north by Cherry Street, to the east and south by railroad lines (currently owned by CSX), and to the west by a W.R. Grace polystyrene insulation manufacturing facility (Figures 1 and 2). Current land use surrounding the site is a mixture of residential and light commercial. The closest residential properties are within a few hundred feet north of the site, on Cherry Street. Other residential areas are located west of the site. These residential areas are visible in historical aerial photographs and historical topographic maps dating back to 1969 [8, 9]. According to U.S. Census 1990 data, 2,196 people lived within 1 mile of the facility when the facility was exfoliating vermiculite (Figure 3).

New Castle is approximately 50 miles north of Pittsburgh, on the western edge of Pennsylvania. Pittsburgh area temperatures range from an average of 30 degrees Fahrenheit in winter (December through February) to an average of 71 degrees Fahrenheit in summer (June through August) [10]. Precipitation in this area ranges from an average low of 7.89 inches in winter to an average high of 11.17 inches in summer [10]. Snowfall typically occurs between November and April, with an annual mean total accumulation of 40.6 inches [11]. Heavy snowfalls of 5 inches or more occur approximately twice a year [11]. Meteorological data from the Youngstown/Warren Regional Airport suggest the predominant wind direction is from the southwest (Figure 4). The airport is 37 miles northwest of the site; therefore actual conditions at the site could vary due to local topography and other factors.

Vermiculite exfoliation

The U.S. Geological Survey (USGS) 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 … the [expanded] vermiculite material is very lightweight and possesses fire- and sound-insulating properties. It is thus well suited for many commercial applications."[12]

The vermiculite ore mined in Libby, Montana, was concentrated and milled to produce different sizes, or grades, of vermiculite. This milled vermiculite was then shipped to the New Castle facility and to other processing facilities throughout the country. Before milling, the raw vermiculite from the Libby mine contained up to 26% asbestos [13]. The various grades of milled vermiculite shipped from Libby contained fibrous amphibole asbestos at concentrations ranging from 0.3% to 7.0% [13].

Commercial exfoliation of vermiculite is a process that can be likened to popping popcorn. Vermiculite is heated in a furnace to temperatures of 1,500 degrees to 2,000 degrees Fahrenheit. As water molecules within the mineral structure are driven off, the vermiculite expands into lightweight, accordionlike nuggets (Figure 5) [12]. The unpopped material that remains after the vermiculite is expanded is called waste rock or stoner rock (Figure 6). Estimates of the asbestos content of the waste rock vary from 2% to 10% (EPA, unpublished data; J. Kelly, Minnesota Department of Health, personal communication, 2002).

In general, vermiculite exfoliation facilities were small-scale operations employing fewer than 50 people. Vermiculite was often delivered to the facilities in bulk by railcar. Workers at the exfoliation facilities used shovels or front-end loaders to manually unload vermiculite from the railcars and store it on the site in open stockpiles or enclosed silos. At many of the facilities, the transfer processes were later automated with screw-type augers and conveyor belts to deliver vermiculite to the storage areas and into the exfoliation furnace. Other manual tasks at these facilities included filling and sealing product bags, adding bags of vermiculite and chrysotile asbestos to the Monokote mixer, managing waste rock (filling bags or transferring bulk material), maintaining equipment, and providing general housekeeping services.

Several equipment and operational changes were implemented at vermiculite exfoliation facilities in response to environmental and worker regulations promulgated throughout the 1970s. Although asbestos emissions from these exfoliation facilities were not regulated under 1970 EPA Clean Air Act amendments, W.R. Grace submitted information to EPA in May 1973 indicating that 19 of their 31 exfoliation facilities had particulate and asbestos emission control equipment that was compliant with the regulations (EPA, unpublished data). As the OSHA permissible exposure level (PEL) for occupational exposure to asbestos steadily decreased from an initial standard of 12 fibers per cubic centimeter of air (f/cc) established in 1971 to the 1994 standard of 0.1 f/cc [14], W.R. Grace initiated employee monitoring and various process design changes to achieve compliance (EPA, unpublished data).

At some exfoliation facilities, respiratory protection (such as dust masks and various types of respirators) was periodically documented for certain job categories in industrial hygiene reports dating back to the early 1970s (EPA, unpublished data). Information is not available to evaluate the use or effectiveness of this respiratory equipment in reducing worker exposures to asbestos. The overall effectiveness depends on a number of factors, including the protection factor of the masks, the effectiveness of the fit testing protocols, and the actual compliance of individuals required to wear the masks. In 1977, W.R. Grace initiated an internal communication program intended to enforce respirator use and provide education to workers regarding the health impacts of smoking combined with asbestos exposure (EPA, unpublished data). The increased risk of lung cancer from smoking combined with asbestos exposure is stated as the basis for an employee “no smoking” policy found in the 1982 W.R. Grace employee handbook (EPA, unpublished data).

Records indicate waste rock and fine particulates from the dust and fiber control equipment at many of the exfoliation facilities was bagged and disposed of at local landfills beginning in the late 1970s and early 1980s [15]. Before that time, very little information is available to track the handling and disposal of waste rock and fine particulates at these facilities. Anecdotal reports indicate the waste rock at some facilities was temporarily stockpiled on the site, these stockpiles were accessible to the public, and children played in them [16, 17]. At one exfoliation facility, workers and nearby community members were encouraged to take waste rock home for personal use [16].

Asbestos and asbestos-related health effects

Asbestos minerals fall into two groups, serpentine and amphibole. Serpentine asbestos has relatively long and flexible crystalline fibers; this class includes chrysotile, the predominant type of asbestos used commercially. Fibrous amphibole asbestos minerals are brittle and have a rod- or needle-like shape. Amphibole minerals regulated as asbestos by OSHA include five classes: crocidolite, amosite, and the fibrous forms of tremolite, actinolite, and anthophyllite. Other unregulated amphibole minerals, including winchite, richterite, and others, can also exhibit fibrous asbestiform properties [12].

Vermiculite from Libby was found to contain several types of asbestos fibers including the amphibole asbestos varieties tremolite and actinolite and the related fibrous asbestiform minerals winchite, richterite, and ferro-edenite [12]. In this report, the terms Libby asbestos and Libby amphibole will be used to refer to the characteristic composition of asbestos contaminating the Libby vermiculite.

Individual asbestos fibers are too small to be seen without a microscope or other laboratory instruments. However, asbestos can sometimes be visible when many fibers form together in “bundles” or when the asbestos forms in nonfibrous blocky fragments (Figure 6). Asbestos fibers do not have any detectable odor or taste. They do not dissolve in water or evaporate in the air, although individual asbestos fibers can easily be suspended in the air. Asbestos fibers do not move through soil. They are resistant to heat, fire, and chemical and biological degradation. As such, they can remain virtually unchanged in the environment over long periods of time [18].

Appendix B provides an overview of several concepts relevant to the evaluation of asbestos exposure, including analytical techniques and federal regulations concerning asbestos.

In terms of human exposure, ATSDR considers the inhalation route of exposure to be the most significant in the current evaluation of sites that received vermiculite from Libby. Although both ingestion and dermal exposure routes may exist, health risks from these exposures are low compared with health risks from the inhalation route [18]. Health effects associated with breathing asbestos include the following.

- *Malignant mesothelioma*—Cancer of the membrane (pleura) that encases the lungs and lines the chest cavity. This cancer can spread to tissues surrounding the lungs or other organs. The majority of mesothelioma cases are attributable to asbestos exposure [18].

- *Lung cancer*—Cancer of the lung tissue, also known as bronchogenic carcinoma. The exact mechanism relating asbestos exposure with lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk for lung cancer [18].

- *Noncancer effects*—These include asbestosis (scarring of the lung, and reduced lung function caused by asbestos fibers lodged in the lung); pleural plaques (localized or diffuse areas of thickening of the pleura); pleural thickening (extensive thickening of the pleura which may restrict breathing); pleural calcification (calcium deposition on pleural areas thickened from chronic inflammation and scarring); and pleural effusions (fluid buildup in the pleural space between the lungs and the chest cavity) [18].

Numerous studies of occupationally exposed workers conclusively demonstrate that inhalation of asbestos can increase the risk for mesothelioma, lung cancer, and various noncancer health effects [18]. Several studies have documented health impacts consistent with asbestos-related disease in workers and others associated with the Libby mine [19-24]. Asbestos-related health impacts to workers associated with vermiculite exfoliation facilities have also been documented [25, 26].

Exposure to asbestos does not necessarily mean an individual will get sick. The frequency, duration, and intensity of the exposure, along with personal risk factors such as smoking, history of lung disease, and genetic susceptibility determine the actual risk for an individual [18]. The mineralogy and size of the asbestos fibers involved in the exposure are also important in determining the likelihood and nature of potential health impacts. Exposure to amphibole asbestos fibers that are long (greater than 10 micrometers) increases the risk of carcinogenic health effects such as mesothelioma and lung cancer [18, 27, 28]. Short amphibole fibers (less than 5 micrometers) are thought to be less important in inducing carcinogenic effects, but they may play a role in increasing the risk for noncancer effects such as asbestosis [29]. The fibrous forms of amphibole asbestos are potentially more toxic than other commonly encountered serpentine fibers (for example, chrysotile) [18, 28, 30].

Chronic exposure is a significant risk factor for asbestos-related disease. However, brief episodic exposures may also contribute to disease. A brief, high intensity exposure from working just two summers at a vermiculite exfoliation facility in California has been linked to a case of fatal asbestosis [26]. Very little conclusive evidence is available regarding the health effects of low-dose, intermittent exposures to asbestos. A “safe” exposure level below which health effects are unlikely has yet to be formally defined in federal regulations and policies.

Methods

Data sources

ATSDR obtained site-specific environmental sampling and facility operational data from either EPA or W.R. Grace, the company that formerly owned the Libby mine and many of the exfoliation sites around the country.

Current environmental data for the site consisted of indoor air, outdoor soil, and bulk material sampling results from investigations conducted in 1998 , 1999, 2000, 2002, and 2003 by either W.R. Grace or EPA Region 3 [1-3].

EPA assembled and summarized W.R. Grace invoices for shipments of vermiculite from the Libby mine to vermiculite processing sites across the country. These invoice records corresponded to the period of W.R. Grace's ownership of the Libby mine, which began in 1963. Limited information was available about production and shipping of vermiculite prior to 1964. ATSDR used EPA's summary of invoices to estimate vermiculite tonnage figures for the New Castle facility (EPA, unpublished data, April 2001).

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 New Castle site from a database of W.R. Grace documents. EPA obtained this document database, comprising approximately 2.5 million electronic image files, during the investigation of the Libby mine. The database contains confidential business information as well as private information that is not available to the public.

Other sources of data used for evaluating the site include U.S. Census data, aerial photographs, and site visits by ATSDR, EPA, and PADEP.

Site evaluation methodology

The site evaluation consisted of (1) identifying and assessing complete or potential exposure pathways to Libby asbestos for the past, present, and future and (2) determining whether the exposure pathways represent a public health hazard. The latter determination is qualitative or semiquantitative at best due to a number of underlying limitations, including difficulties in quantifying asbestos exposures, assessing asbestos toxicity, and quantifying risks for carcinogenic and noncarcinogenic health endpoints. A more rigorous, quantitative approach of calculating the risk of potential health impacts was not possible given the limitations in available data.

ATSDR used knowledge gained from investigations in Libby, Montana, and at a few early investigations at vermiculite exfoliation facilities to identify several likely pathways for occupational and community exposure to asbestos at such facilities (Appendix C). As stated previously, ATSDR considered only the inhalation route of exposure at the Phase 1 sites.[3]

An exposure pathway consists of five elements: a *source* of contamination, a *medium* through which the contaminant is transported, a *point of exposure* where people can come into contact with the contaminant, a *route of exposure* by which the contaminant enters or contacts the body, and a *receptor population*. A pathway is considered complete only if all five elements are present and connected. More information on exposure pathways is included in Appendix A.

To determine whether complete or potential exposure pathways pose a public health hazard, ATSDR considered available site-specific exposure data (e.g., the frequency, duration, and intensity of exposure). Although a few risk-based metrics are available to evaluate levels of airborne asbestos, no *health-based* comparison values are available to indicate "safe" levels of asbestos in air, soil, dust, or other bulk materials such as vermiculite and waste rock. In addition, very little information is available about the health risks associated with low-dose, intermittent exposure to amphibole asbestos. These limitations necessitate that ATSDR use a conservative approach to public health decision making for the site.

[3] ATSDR has selected 28 sites for the first phase of site evaluations. The foreword provides the criteria for selecting the sites.

For asbestos fiber levels in air, ATSDR used the current risk-based Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 0.1 fibers per cubic centimeter (f/cc) of air as one metric to assess asbestos inhalation exposure for workers [14]. The 0.1 f/cc OSHA PEL, calculated as an 8-hour time-weighted average, represents the upper limit of exposure for a worker during a normal work day. It is worthwhile to note that OSHA's final rules for occupational exposure to asbestos acknowledged that "…a significant risk remains at the PEL of 0.1 f/cc" [14]. 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 activities [14].

ATSDR acknowledges two community exposure guidelines for airborne asbestos established by interagency workgroups following the World Trade Center collapse in 2001. For short-term (less than 1 year) exposures, 0.01 f/cc asbestos in indoor air was developed as an acceptable reoccupation level for occupants of residential buildings [31]. A risk-based comparison value of 0.0009 f/cc for asbestos in indoor air was established to be protective under long-term residential exposure scenarios [32]. All three exposure values (the OSHA PEL and the World Trade Center community guidance values) are primarily applicable to airborne chrysotile asbestos fibers that have lower toxicity than Libby asbestos.

In the absence of any health- or risk-based comparison levels for asbestos in soil, dust, or bulk materials, ATSDR is evaluating these exposure pathways qualitatively, with strong consideration given to known or potential exposure scenarios at each site. For example, to determine whether asbestos in soil poses a public health hazard at a site, ATSDR is considering the concentration of asbestos in the soil, the horizontal extent of asbestos-contaminated surface areas, the presence or absence of ground cover, the frequency and type of activities that disturb soil, and accessibility. Soil containing Libby asbestos at levels greater than or equal to 1% is generally considered a health hazard requiring remediation. Depending on site-specific exposure scenarios, remediation or other measures may also be appropriate to prevent exposure to soil containing less than 1% Libby asbestos. Because federal standards regulate materials that contain more than 1% asbestos [33, 34], the 1% value has been used as an action level for soil remediation activities at a number of sites. EPA and ATSDR recognize that this 1% value is not derived from a risk assessment or any other type of health-based analysis; therefore, it does not ensure that airborne asbestos fibers resuspended by disturbing these soils will be below levels protective of human health [35]. In fact, recent activity-based studies have shown that disturbing soil containing less than 1% Libby asbestos can resuspend fibers and generate airborne concentrations at or near the OSHA permissible exposure limit [36, 37].

Results

A summary of the exposure pathway evaluations for the New Castle site is presented in Table 2. The findings for each of the pathways are presented in the following paragraphs.

Table 2. Summary of pathway evaluations for the New Castle facility

Pathway Name	Exposure Scenario	Timeframe	Pathway Status*	Public Health Hazard Determination*
Occupational	Former workers inhaling Libby asbestos in and around the facility during handling and processing of contaminated vermiculite	**Past (1969–1992)**	**Complete**	**Public health hazard**
		Past (1992–2004)	Potential	No apparent public health hazard
	Current on-site workers inhaling Libby asbestos from residual contamination inside former processing buildings or in on-site soil (residual contamination, buried waste)	Present	Eliminated	No public health hazard
		Future	Eliminated	No public health hazard
Household Contact	Household contacts inhaling Libby asbestos brought home on workers' clothing, shoes, and hair	**Past (1969–1992)**	**Complete**	**Public health hazard**
		Past (1992–2004)	Potential	No apparent public health hazard
		Present	Eliminated	No public health hazard
		Future	Eliminated	No public health hazard
Community	Facility emissions: Community members or nearby workers inhaling asbestos fibers from plant emissions during handling and processing of contaminated vermiculite	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	Waste piles: Community members (particularly children) inhaling asbestos while playing in or disturbing on-site piles of contaminated vermiculite or waste rock	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	On-site soil: Community members inhaling Libby asbestos from contaminated on-site soil (residual contamination, buried waste)	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	Residential outdoor: Community members inhaling Libby asbestos while using contaminated vermiculite or waste material at home (for gardening, driveways, fill material)	Past	Potential	Indeterminate
		Present/ Future	Potential	Indeterminate
	Residential indoor: Community members disturbing household dust containing Libby asbestos fibers from plant emissions or residential outdoor waste	Past	Potential	Indeterminate
		Present/ Future	Potential	No apparent public health hazard

*Pathway status descriptions and public health hazard category definitions are provided in Appendix A.

Bold type indicates a completed pathway that is considered a public health hazard.

Occupational pathway (past: 1969-1992 timeframe)

The occupational exposure pathway for former workers exposed to airborne Libby asbestos in and around the facility during handling and processing of vermiculite during 1969–1992 is considered complete. On the basis of available information concerning the intensity, frequency and duration of past occupational exposures, this exposure pathway is considered a public health hazard.

Personal sampling results for workers at the facility indicate airborne fiber levels consistently in the range of 1 f/cc to 10 f/cc in the 1970s (Figure 7). These fiber levels were measured using phase contrast microscopy (PCM) analytical techniques.[4] Samples collected in the 1970s near the stoner deck, where the waste rock was separated from the expanded vermiculite product,

[4] PCM analytical techniques cannot detect fibers less than 0.25 (<0.25) µm in diameter and cannot distinguish between asbestos and nonasbestos fibers. Reference Appendix B for more information about analytical techniques used for asbestos.

indicated airborne PCM fiber concentrations as high as 26 f/cc (EPA, unpublished data). By the late 1980s, measured airborne PCM fiber concentrations from both personal and area sampling inside the facility were below the current OSHA PEL of 0.1 f/cc. Personal samples, typically collected within a worker's breathing zone, were associated with specific workers. Most of the area sampling was conducted at consistent locations in the exfoliation process where fibers were likely to be released (for example, the furnace baghouse, the furnace stoner deck where waste rock and expanded product were separated, the waste rock hopper) (EPA, unpublished data).

Although no sampling data are available during 1969–1971, airborne fiber levels during this period were probably at or above the levels documented in 1972 (1 f/cc to 10 f/cc). Measured airborne fiber levels within the vermiculite exfoliation facilities decreased throughout the 1970s and 1980s as W.R. Grace responded to federal OSHA requirements[5] to protect workers from occupational asbestos exposure (EPA, unpublished data). Asbestos exposure levels for workers could have been much higher before the OSHA regulations were first introduced in 1971. Asbestos exposure would also be higher for workers who manually performed some of the material handling processes, such as unloading vermiculite deliveries from railcars, transferring vermiculite into furnace hoppers, and transferring bulk quantities of waste rock.

The MK-3 fireproofing product manufactured at New Castle until July 1973 contained 10% to 19% chrysotile as an ingredient (EPA, unpublished data). MK-3 also contained vermiculite. Workers involved in mixing and packaging MK-3 may have been exposed to higher levels of airborne asbestos because they handled both chrysotile and amphibole asbestos-contaminated vermiculite.

The frequency and duration of former worker exposure varied depending on their job assignment, facility operation schedule, and period of employment. Based on data regarding the total hours of furnace operation in 1978, 1979, and 1980, the New Castle facility probably exfoliated vermiculite 16 hours a day (in two 8-hour shifts), 5 days a week (EPA, unpublished data). The New Castle facility reportedly employed 18 people in 1989, 13 of whom lived in New Castle (EPA, unpublished data). The length of employment for workers at the New Castle facility is unknown, although one employee was listed in the industrial hygiene reports in 1976 and again in 1988 (EPA, unpublished data). Workers appeared to perform the same job assignment throughout the day, such as bagging product, operating the furnace, or mixing Monokote product (EPA, unpublished data).

An industrial hygiene report from 1988 indicated some workers at the New Castle facility had disposable, filtering face piece dust masks (3M 8710 model); however reports from earlier years did not mention worker use of respiratory protection (EPA, unpublished data). Information is not available to evaluate the overall effectiveness of respiratory equipment in reducing worker exposures to asbestos at this facility. 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 wear the masks. The New Castle facility had a shower and locker room area for workers to change clothes (EPA, unpublished data). Information is not available to evaluate whether workers used these facilities.

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[5] Historically, the OSHA PEL for airborne asbestos has been lowered a number of times since it was first introduced: 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).

Although most personal and area sampling data are associated with specific process operations, Libby asbestos fibers were released into the facility air throughout the workday during vermiculite processing and handling. In 1972, several samples collected in the general warehouse area indicated airborne fibers at levels ranging from 0.6 f/cc to 2.9 f/cc (EPA, unpublished data).

Workers could have been exposed to Libby asbestos outside the facility as well. Fugitive emissions from loading, unloading, or transferring bulk vermiculite, bulk vermiculite products, or waste rock resulted in airborne asbestos fiber releases outside the facility. Information provided to EPA in 1978 by a company that exfoliated Libby vermiculite indicated airborne fiber levels were as high as 245 f/cc in the unloading area where unexpanded vermiculite was dumped from rail cars [38]. Stack emissions from the furnaces also contributed to outdoor fiber releases. W.R. Grace indicated they would have particulate and asbestos control equipment on the New Castle furnace emission stacks by the end of 1974 (EPA, unpublished data). Insufficient information is available to determine when this equipment was actually installed or how effective it was in controlling asbestos emissions. The concentrations of airborne asbestos fibers in outdoor air around the facility due to fugitive and stack emissions were likely much higher before the control equipment was installed.

Various non-W.R. Grace workers probably visited the New Castle facility periodically to haul waste rock away from the facility, purchase products, pick up products for delivery, or provide services (e.g., construction, electrical, equipment maintenance). These workers were probably exposed to airborne asbestos in and around the facility, but the frequency and duration of their exposures were likely very low. Some data available from other facilities indicate waste haulers were exposed to asbestos as they loaded and unloaded waste rock (EPA, unpublished data). The intensity, frequency, and duration of the exposure to waste haulers may have been higher than the other non-W.R. Grace worker groups. All of these non-W.R. Grace workers were exposed much less frequently and for shorter durations than the full-time workers at the W.R. Grace facility itself.

Occupational pathway (past: 1992–2004 timeframe)

W. R. Grace has not used the site since vermiculite exfoliation ceased in 1992. Since then, a number of workers — including W.R. Grace consultants and contractors and EPA, ATSDR, and PADEP representatives — have been on the site conducting site inspections, sampling, or remediation activities. Worker exposure pathways were potentially complete in these scenarios. Most of the site inspection and sampling efforts were very limited in scope and duration and do not pose a public health hazard to those involved. The site remediation effort conducted in June and July of 2004 was conducted with sufficient engineering controls, worker monitoring, and perimeter air monitoring to ensure the protection of the workers as well as the surrounding neighborhood [4, 7]. The occupational exposure pathway for the 1992 to 2004 timeframe is considered no apparent public health hazard.

Indoor air assessments

W.R. Grace reportedly cleaned the facility and collected 5 air samples in and around the processing building in October of 1996 (EPA, unpublished data). Insufficient information is available to determine whether aggressive sampling was performed (e.g., if the air and dust surrounding the sample pump were disturbed to re-suspend any residual fibers during sampling). Laboratory sample results indicated less than 0.0009 f/cc (the analytical detection limit) at each sample location (EPA, unpublished data). ATSDR has no information concerning health and safety measures used for the W.R. Grace workers or contractors who cleaned the facility prior to sample collection.

EPA Region 3 representatives inspected the site in October 2000, noting that the building was clean and all processing equipment had been removed. EPA collected two samples of material (described as vermiculite and dust) from inside the facility and submitted them for analysis by polarized light microscopy (PLM) in accordance with NIOSH Method 9002. Analytical results indicated asbestos was not detected in either sample [2].

Additional indoor air samples were collected on behalf of W.R. Grace in September 2003 at four locations inside the New Castle facility. Aggressive air sampling was conducted using a leaf blower to re-suspend any residual asbestos fibers into the air. Sample results were reported as 0.0028 f/cc, 0.0062 f/cc, 0.0099 f/cc, and 0.0106 f/cc by PCM analysis (NIOSH Method 7400) [1]. The sample with the highest reported concentration was also analyzed using a transmission electron microscopic (TEM) technique (NIOSH Method 7402); the results identified nonasbestos fibers in the sample, but no chrysotile or amphibole fibers [1].

Collectively, the indoor assessments indicate no remaining source of asbestos fibers (e.g., contaminated vermiculite or dust) inside the building. Some airborne fibers were detected by PCM analysis following aggressive air sampling, however subsequent analysis by transmission electron microscopy (TEM) identified the fibers as nonasbestos[6].

Exterior soil assessments and remediation

W.R. Grace worked with Gould Environmental, Inc. to conduct soil sampling at the site in 1998, 1999, and 2003 [1]. A total of 123 surface and subsurface samples were collected and analyzed by PLM or TEM techniques to characterize the horizontal and vertical extent of asbestos-contaminated soils. The delineation effort extended onto the adjoining CSX property along the south and east borders of the New Castle site. Sample analytical results for the area where waste rock was used as fill material indicated levels of asbestos as high as 12.8%. All sample locations and analytical reports are presented in the summary report developed by Gould Environmental [1].

Using both TEM and PLM analytical techniques, EPA confirmed trace levels of Libby amphiboles in three of six surface and subsurface samples they collected in 2002. Details concerning EPA sample locations and analytical results can be found in their report [3].

As a result of the findings of the soil investigations at the site, W.R. Grace coordinated with PADEP to remediate the site and some of the adjoining CSX property by excavating 7,890 tons of asbestos-contaminated soils in June and July of 2004 [5]. The excavation depth varied from 0.5 feet below ground surface to 12 feet below ground surface over a horizontal footprint of approximately 39,000 square feet [5]. The on-site remediation workers operated under an approved Health and Safety Plan that included worker protective equipment, worker monitoring, and work area and perimeter air monitoring for asbestos and particulate dust [7].[7] PADEP and

[6] TEM methods can distinguish between asbestos and nonasbestos fibers, but PCM techniques cannot.
[7] PADEP, EPA Region 3, and ATSDR reviewed and approved the site Work Plan and Health and Safety Plan documents prior to the remediation effort.

EPA oversight indicated the remediation work progressed in accordance with the approved Work Plan and Health and Safety Plan documents.

Occupational pathway (present/future timeframe)

On the basis of available sampling data, the inside of the building does not have any residual Libby asbestos sources. The areas of asbestos-contaminated soil outside the facility have been excavated and removed. Current and future worker exposure pathways are considered eliminated and therefore pose no public health hazard.

Household contact pathway (past: 1969–1992 timeframe)

Exposure of household contacts to airborne Libby asbestos brought home on the clothing, shoes, and hair of former workers is considered a complete exposure pathway that represents a public health hazard. Although exposure data are not available for household contacts, their exposures are inferred from documented former worker exposures and facility conditions that did not prevent contaminants being brought into the workers' homes.

Vermiculite exfoliation was reportedly a very dusty operation. The New Castle facility had a shower and locker room area for workers to change clothes (EPA, unpublished data). Information is not available to evaluate whether workers used them. Although on-site laundering facilities were considered in 1984, they were not implemented due to union disputes (EPA, unpublished data). Members of the households of W.R. Grace workers could have been exposed to Libby asbestos fibers if the workers did not shower or change clothes before leaving work. Family members or other household contacts could have been exposed to asbestos by direct contact with the worker or by laundering clothing. These exposures cannot be quantified without information concerning the levels of asbestos on workers' clothing and behavior-specific factors (e.g., worker practices, household laundering practices). However, exposure to asbestos resulting in asbestos-related disease in family members of asbestos industry workers has been well-documented [39, 40].

Household contact pathway (past: 1992–2004 timeframe)

Recent remediation activities at the site were reportedly conducted with appropriate personal protective equipment and monitoring for workers [4, 5]. Exposures to household contacts of remediation workers on the site are considered no apparent public health hazard.

Household contact pathway (present/future timeframe)

Available sampling data indicate that the inside of the building does not have any residual sources of Libby asbestos. The areas of asbestos-contaminated soil outside the facility have been excavated and removed. Current and future worker exposure pathways are considered eliminated; therefore the exposure pathway to household contacts of these workers is considered no public health hazard.

Community pathways (past timeframe)

Community members who lived or worked around the New Castle facility during 1969–1992 could have been exposed to Libby asbestos from facility emissions, by disturbing or playing on on-site waste rock piles, by disturbing on-site soil or from direct contact with waste rock brought home for personal use. Information is insufficient to reconstruct the magnitude, frequency, or duration of these community exposures; therefore, they are considered an indeterminate public health hazard.

When the facility was operating, community members and area workers could have been exposed to Libby asbestos fibers released into the ambient air from fugitive emissions or from furnace stack emissions. The prevalent wind direction is from the southwest (Figure 4); therefore, the residential homes north of the facility were downwind some of the time. This residential area was present when the New Castle facility began operating in 1969 [8, 9].

Fugitive emissions from loading, unloading, or transferring bulk vermiculite or waste rock resulted in airborne asbestos fiber releases in areas outside the facility. Stack emissions from the furnaces also contributed to outdoor fiber releases. In 1977, correspondence between the Pennsylvania Department of Environmental Resources (PADER) and W.R. Grace indicated that neighbors of the New Castle facility were complaining about odors and emissions from the plant [41-43]. A PADER representative documented visible emissions he described as smoke [42, 43].

W.R. Grace indicated they would have particulate and asbestos control equipment on the New Castle process stacks by the end of 1974 (EPA, unpublished data). Insufficient information is available to determine when this equipment was actually installed or how effective it was in controlling asbestos emissions. The concentrations of airborne asbestos fibers in outdoor air around the facility due to fugitive and stack emissions were likely much higher before the pollution control equipment was installed. Specific information concerning airborne fiber levels resulting from stack emissions is not available for the New Castle site. 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 (EPA, unpublished data). Particulates captured by the filters in the pollution control equipment (when installed) reportedly contained 1%–3% friable Libby asbestos (EPA, unpublished data).

Community members (particularly children) playing in or otherwise disturbing piles of contaminated vermiculite, waste rock, or contaminated soil at the facility in the past is considered a potential exposure pathway. When the facility was operating, waste rock may have been temporarily stockpiled on the site and accessible to children and other community members. Anecdotal or photographic evidence of children playing in on-site waste piles is available for several similar exfoliation facilities [16, 17, 44]. After the New Castle facility closed in 1992, the site reportedly remained vacant. During a site visit in 2002 ATSDR representatives noted children's toys on the site, indicating the area may have been used by trespassers [45]. The site is not fenced to restrict public access [45].

Community members' use of contaminated vermiculite or waste material at home is considered a potential exposure pathway. At a former vermiculite exfoliation facility in Minneapolis, Minnesota, waste rock was advertised as "free crushed rock," and community members took it home to use in their yards, gardens, and driveways [16]. Insufficient information is available to determine whether this happened in the community around the New Castle facility while the facility operated. If so, people may have been exposed to airborne Libby asbestos by handling waste rock and working with it in their yards and gardens.

Libby asbestos fibers could have infiltrated homes surrounding the New Castle facility from plant emissions or from waste rock brought home for personal use. Insufficient information is available concerning past air emissions and community use of waste rock; therefore, residential indoor exposure to Libby asbestos fibers is an indeterminate past public health hazard.

Community pathways (present/future timeframe)

Most community members who live or work near the site now are not being exposed to Libby asbestos from the site. Several community exposure pathways, such as ambient air emissions, on-site vermiculite and waste rock piles, and asbestos-contaminated soil on the site, have been eliminated, and therefore pose no public health hazard to the current community. Pathways involving exposure of individuals to waste rock brought home from the facility in the past for personal use as fill material, driveway surfacing, or soil amendments represent potential exposure pathways. Because not enough information is available to determine whether individuals brought waste rock home for personal use, this exposure pathway is considered an indeterminate public health hazard.

During the site visit in 2002, ATSDR staff members noted that no waste piles were observed at the site [45]. The present and future exposure pathways to on-site waste piles are considered eliminated and therefore pose no public health hazard to community members. Present and future exposure to Libby asbestos from facility air emissions has also been eliminated because the facility is no longer in operation. Areas of asbestos-contaminated soil at the New Castle site and on the adjoining CSX property were excavated and removed in 2004, effectively eliminating this exposure pathway.

Not enough information is available to determine whether individuals brought waste rock home for personal use. Vermiculite or waste rock brought home from the facility in the past could still be a source of exposure today. If the asbestos-containing material is covered (with soil, grass, or other vegetation) and is not disturbed, the asbestos fibers will not become airborne and will not pose a public health hazard.

Facility emissions have ceased and are no longer a source of potential contamination in nearby homes. Residual Libby asbestos from potential past sources is possible, though housekeeping (particularly wet cleaning methods) over the past years would probably have removed any residual Libby asbestos in area homes. The only likely current source of Libby asbestos fibers in the home would be from waste rock brought home for residential use. Insufficient information is available to determine whether waste rock was used in the community. However, the waste rock alone would not be expected to contribute significantly to residential indoor exposure. The current and future residential indoor exposure pathways are considered no apparent public health hazard for community members.

Discussion

Exposure pathway evaluations

While the facility was operating, processing and handling of asbestos-contaminated vermiculite at the New Castle facility clearly resulted in asbestos exposures to former workers and their household contacts. Sufficient site- and process-specific information is available to consider these exposures a public health hazard. On the basis of available information, ATSDR estimates that 60 to 120 former workers were exposed during the time the plant operated. The frequency and duration of former worker exposure depended upon the workers' job assignments, facility operation schedules, and periods of employment. Use of respiratory protection would also influence the degree of worker exposure to airborne asbestos fibers.

Community members who lived or worked near the New Castle facility in the past could have been exposed to Libby asbestos from facility emissions, by disturbing or playing on on-site waste rock piles, by disturbing on-site soil or from direct contact with waste rock brought home for personal use. Very little information is available to verify these community exposures or to quantify their magnitude, frequency, or duration. They are therefore considered an indeterminate public health hazard. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached downwind residential areas from 1969 through 1974 (i.e., before emission control equipment was installed) and (2) on-site waste rock piles that may have been accessible to community members, especially children. Children who were exposed to asbestos are a particularly sensitive population because of the length of time the asbestos fibers could remain in their lungs and the long latency period of asbestos-related diseases.

Most community members who live or work near the site now are not being exposed to Libby asbestos from the site. Several community exposure pathways that existed while the facility was operating, such as plant emissions and on-site vermiculite and waste rock piles, have been eliminated. However, not enough information is available to determine whether some individuals may still be exposed to Libby asbestos through direct contact with waste rock used in the community in the past as fill material, driveway surfacing, or as an amendment for soil.

Potential health impacts

Exposure to asbestos does not necessarily mean an individual will get sick. The frequency, duration, and intensity of the exposure, along with personal risk factors such as smoking, history of lung disease, and genetic susceptibility determine the actual risk for an individual. The mineralogy and size of the asbestos fibers involved in the exposure are also important in determining the likelihood and the nature of potential health impacts.

Given the limited or nonexistent exposure data available to characterize many of the pathways associated with Libby asbestos at the New Castle site, the risk of future health impacts for the exposed populations cannot be quantified. ATSDR is working with state health department partners across the country to review historical health statistics for communities around many of the facilities that processed Libby vermiculite, including the New Castle facility. As this information is reviewed and validated, ATSDR's Division of Health Studies will release the findings of the health statistics reviews in a separate summary report.

Limitations

A number of site-specific limitations affect the exposure pathway evaluation and health risk characterization efforts at the New Castle site. Exposure data are not available for many of the past and current exposure pathways. This information may never be available for the past exposure scenarios. Site-specific sampling results that are available do not typically describe the mineralogy and fiber size distribution of the asbestos detected. This information is critical to quantitatively assess the actual toxicity and potential health impacts associated with exposure. Historical personal and area samples collected at the New Castle facility and analyzed by phase contrast microscopy (PCM; see Appendix B) refer to measured fiber levels. However, fibers other than asbestos may have been counted in the sample analyses. PCM techniques alone cannot distinguish between asbestos fibers and nonasbestos fibers. PCM techniques also cannot detect very thin fibers (fibers that have diameters less than 0.25 micrometer (µm)).

Limitations in the current state of the science related to amphibole asbestos also influence the evaluation of exposure to Libby asbestos and the associated health risks. Health-based comparison values representing “safe” levels of amphibole asbestos in air have not been developed. Determining “safe” levels of asbestos in other environmental media (e.g., soil, dust) is even more difficult because a safe level is not determined by the inherent asbestos fiber or mass concentration in the medium itself, but rather on the potential airborne fiber exposure associated with disturbing asbestos-contaminated soil or dust. Two options are available to estimate the resuspension of asbestos fibers from soil or dust into air during realistic exposure scenarios, but they are both relatively difficult and costly to implement. One option is to conduct site-specific field tests that directly measure airborne fiber levels during simulated exposure scenarios. The other option is to collect site-specific soil samples, analyze them in accordance with EPA 540/R/97/28[8] to obtain the fraction of fibers in the soil that can be released into the air, and then use this information in an appropriate air modeling effort to simulate exposure scenarios.

An adequate toxicological model to evaluate the noncarcinogenic health risks of amphibole asbestos exposure does not exist. The current EPA model used to quantify carcinogenic health risks due to asbestos exposure 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 their asbestos risk methodologies. A draft model for quantifying carcinogenic health risks associated with amphibole asbestos has been developed, although it has not been formally accepted through the EPA review process [27]. This draft methodology requires detailed asbestos sample characterization beyond what was generated at these sites. Data gaps in scientific research related to Libby asbestos have resulted in ongoing and largely unresolved discussions in the scientific community regarding the potential health risks of low-level, intermittent exposure and the relative importance of short asbestos fibers (fibers <5 micrometers in length) in noncancer health effects [28, 29].

Additional considerations and limitations associated with asbestos-related evaluations are discussed in Appendix B.

Public health response

Most of the current and future exposure pathways associated with Libby asbestos at the New Castle site have been eliminated or do not pose a public health hazard. ATSDR characterized the presence of waste rock in the community as a potential exposure pathway that poses an indeterminate health hazard. Insufficient information is available to determine whether this pathway is complete or whether the identified uses of this waste material in the past (at other facilities) would result in significant exposures today. Providing awareness and information to people in the neighborhood surrounding the New Castle facility is an appropriate public health response at this time.

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[8] U.S. Environmental Protection Agency. Superfund method for the determination of releasable asbestos in soils and bulk materials. Washington DC:US EPA Office of Solid Waste and Emergency Response; 1997.

ATSDR characterized several historical exposure pathways as either confirmed or indeterminate public health hazards. Increased health risk due to past exposure to Libby asbestos is difficult to quantify, and actual asbestos-related heath effects are difficult to treat. The latency period between asbestos exposure and disease can be 15 to 20 years or more. Asbestos-related diseases are not curable, though some treatments are available to ease the symptoms and perhaps slow disease progression. People who have been exposed to asbestos can take steps to control their risk or susceptibility, such as preventing additional exposure to asbestos and refraining from smoking.

At this site, where little can be done about past asbestos exposure or possible resulting health effects, promoting awareness and offering health education to exposed and potentially exposed populations is an important intervention strategy. For exposed individuals (e.g., former workers, their household contacts, and children who played in waste piles), health messages should be structured to facilitate self-identification and encourage individuals to either inform their regular physician of their asbestos exposure or consult a physician with expertise in asbestos-related lung disease. Health care provider education in this community would facilitate improved surveillance and recognition of atypical risk factors (for example, those related to nontraditional asbestos-related occupations or nonoccupational exposure) that can contribute to asbestos-related diseases.

Conclusions, recommendations, and public health action plan

Former workers and their household contacts (1969–1992)

People who worked at the W.R. Grace New Castle facility during 1969–1992 were exposed to airborne levels of Libby asbestos above current occupational standards. Chronic exposure to airborne asbestos at these elevated levels increased a worker's risk for asbestos-related disease and therefore posed a *public health hazard*.

Members of the households of former workers may have been exposed to asbestos fibers if the workers did not shower or change clothes before leaving work. Although exposure data are not available for household contacts of former exfoliation workers, their exposures are inferred from documented worker exposure and facility conditions. This pathway therefore represents a *public health hazard* to members of the households of former workers.

Recommendations

- Promote awareness of past asbestos exposure among former workers and members of their households.
- Encourage former workers and their household contacts to inform their regular physician about their exposure to asbestos. If former workers or their household contacts are concerned or symptomatic , they should be encouraged to see a physician who specializes in asbestos-related lung diseases.

Public health action plan

- ATSDR will develop and disseminate reliable and easily accessible information concerning asbestos-related health issues for exposed individuals and health care providers.

- ATSDR will publicize the findings of this health consultation in the community around the site. ATSDR will make the report accessible on the Internet and in the community.
- ATSDR will notify former workers for whom we have contact information and provide them with exposure information and health information about asbestos.
- ATSDR is researching and determining the feasibility of conducting additional worker and household contact follow-up activities.

Current or future workers and their household contacts

Available sampling data indicate the inside of the building does not have any residual sources of Libby asbestos. The areas of asbestos-contaminated soil outside the facility have been excavated and removed. Current and future worker exposure pathways are considered eliminated, and therefore pose no public health hazard to the workers or to their household contacts.

Community members who lived near the facility (1969–1992)

The people in the community around the site during the time the New Castle facility processed Libby vermiculite could have been exposed to Libby asbestos fibers by disturbing or playing in on-site soil or waste piles, from plant emissions, from waste rock brought home for personal use, or from indoor household dust that contained Libby asbestos from one or more outside sources. Insufficient information is available to determine whether these exposures occurred, how often they may have occurred, or what concentrations of airborne Libby asbestos may have been present at the time of exposure. This information may never be available. Because critical information is lacking, these past exposure pathways for community members are considered *indeterminate public health hazards*.

Recommendations

- Promote awareness of potential past asbestos exposures among community members who lived near the facility during 1969–1992. Provide these people with easily accessible materials that will assist them in identifying their own potential for past exposure.
- Encourage persons who lived in the community in the past and feel they were exposed to inform their regular physician about their potential asbestos exposure.

Public health action plan

- ATSDR will develop reliable, easily accessible, and understandable information concerning asbestos-related health issues for individuals who may have been exposed and for health care providers in the area.
- ATSDR will publicize the findings of this health consultation within the community around the site. ATSDR will make the report accessible in the community and on the Internet.

Community members who live near the site now (1992 to present)

The New Castle facility no longer processes vermiculite at the site; they stopped processing vermiculite from Libby in 1992. Many of the community exposure pathways, such as ambient emissions and disturbing or playing on on-site waste piles, have been eliminated. Areas of asbestos-contaminated soil at the site and surrounding property have been excavated and disposed of appropriately. These exposure pathways pose *no public health hazard* to the people who live in the surrounding community.

Currently, individuals in the community could be exposed to airborne Libby asbestos from waste rock that may have been brought home from the facility in the past and used as fill material, for gardening, for paving driveways, or for other purposes. This exposure pathway is an *indeterminate public health hazard* because insufficient information is available to determine whether waste rock was used in the community.

Recommendations

- Promote awareness of potential asbestos exposure from direct contact with waste rock brought home from the facility in the past. Provide easily accessible materials to help community members identify their own potential for exposure.

Public health action plan

- ATSDR will develop reliable, easily accessible, and understandable information concerning asbestos-related health issues for individuals who may have been exposed and for health care providers in the area.
- ATSDR will publicize the findings of this health consultation in the community around the site. ATSDR will make the report accessible in the community and on the Internet.

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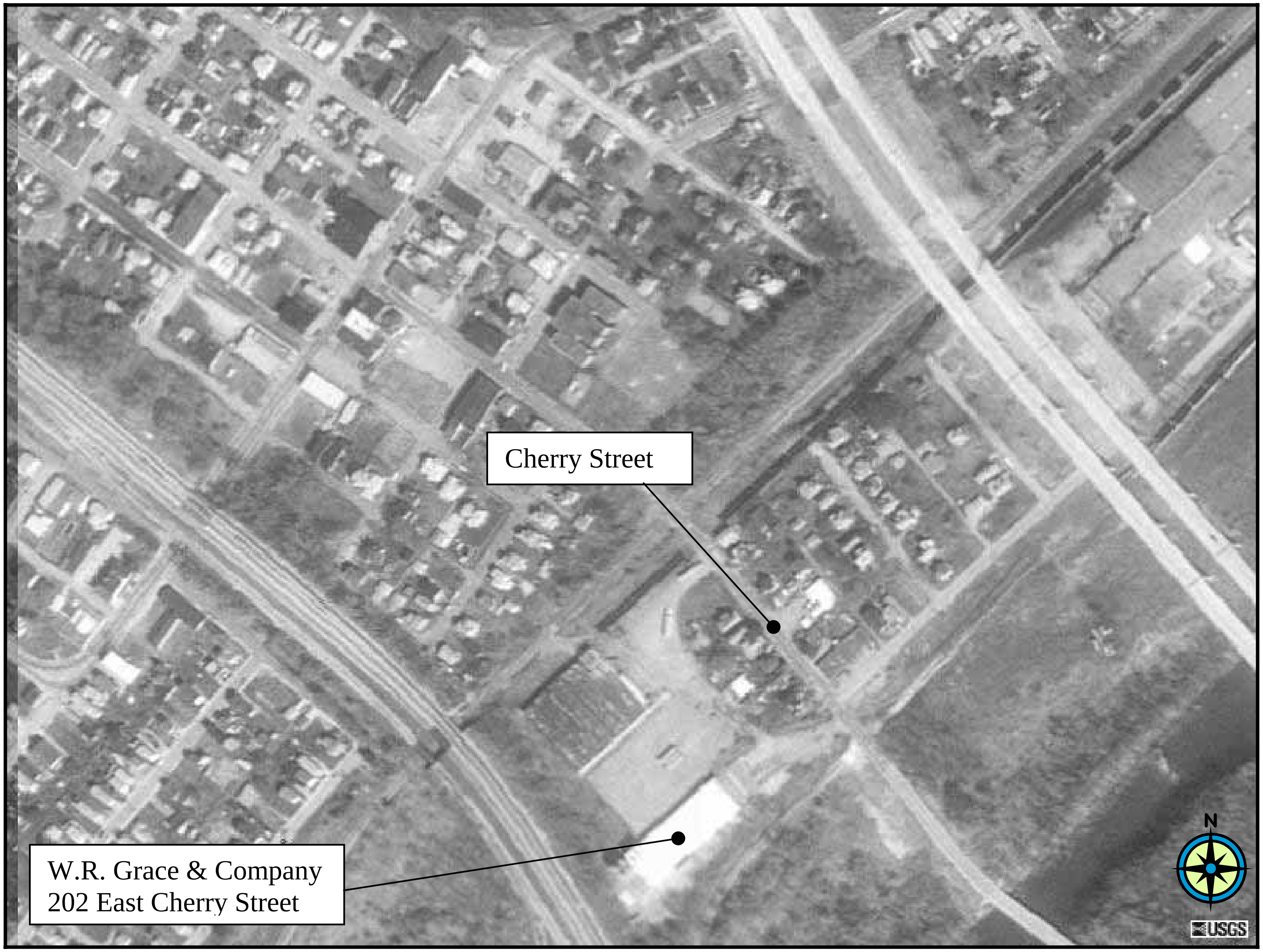
Figures

Figure 1. Aerial photograph of the site area, 1993*



* Source: Aerial Photography Print Service for 202 East Cherry Street, New Castle, Pennsylvania. Historical aerial photograph from US Geological Survey (1993). Milford, Connecticut: Environmental Data Resources, Inc.; 2004.

Figure 2. Site map showing area of remediation*

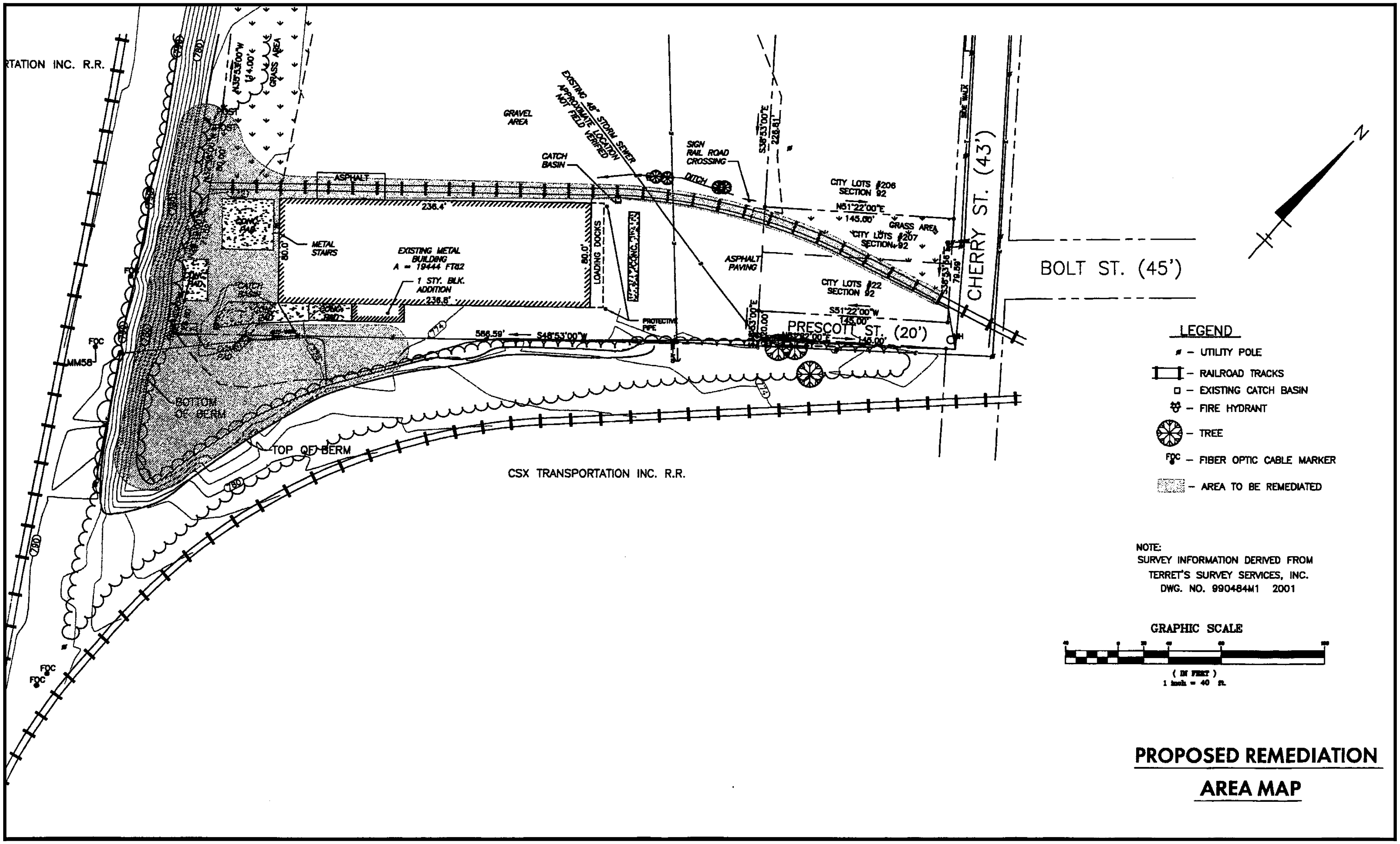


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Figure 3. 1990 US census data for the area surrounding the New Castle, PA site

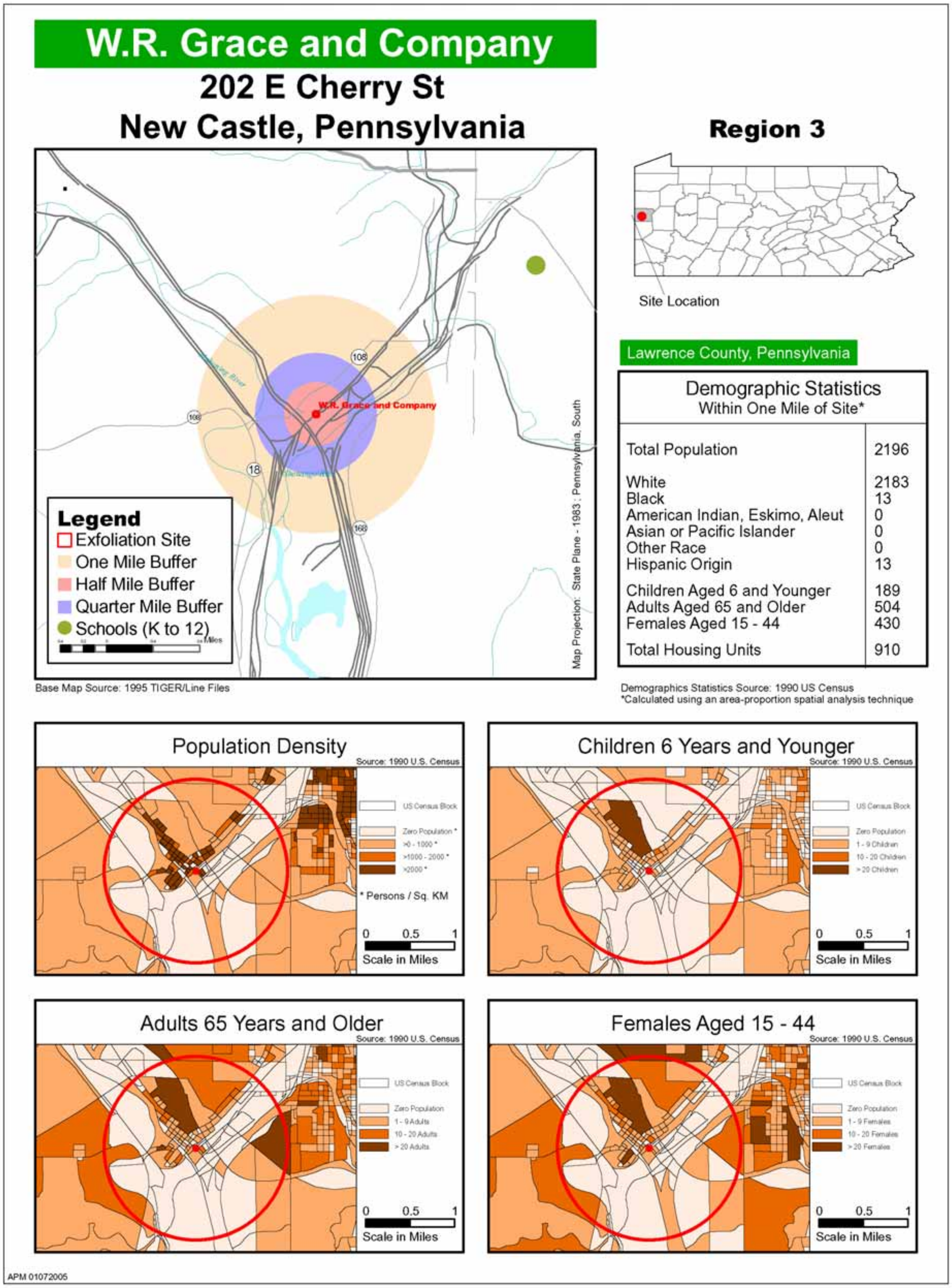


Figure 4. Meteorological data from the Youngstown/Warren Regional Airport

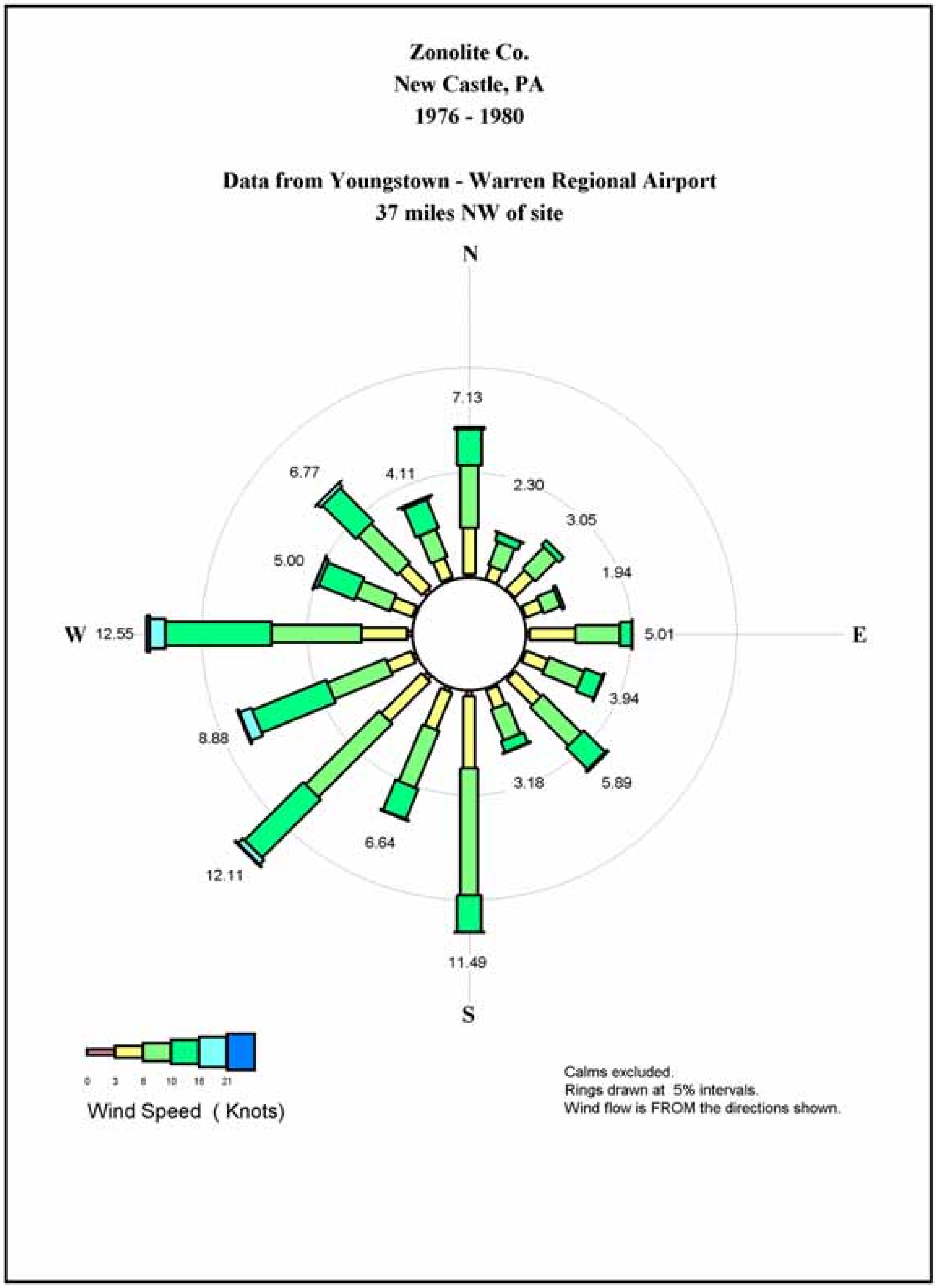
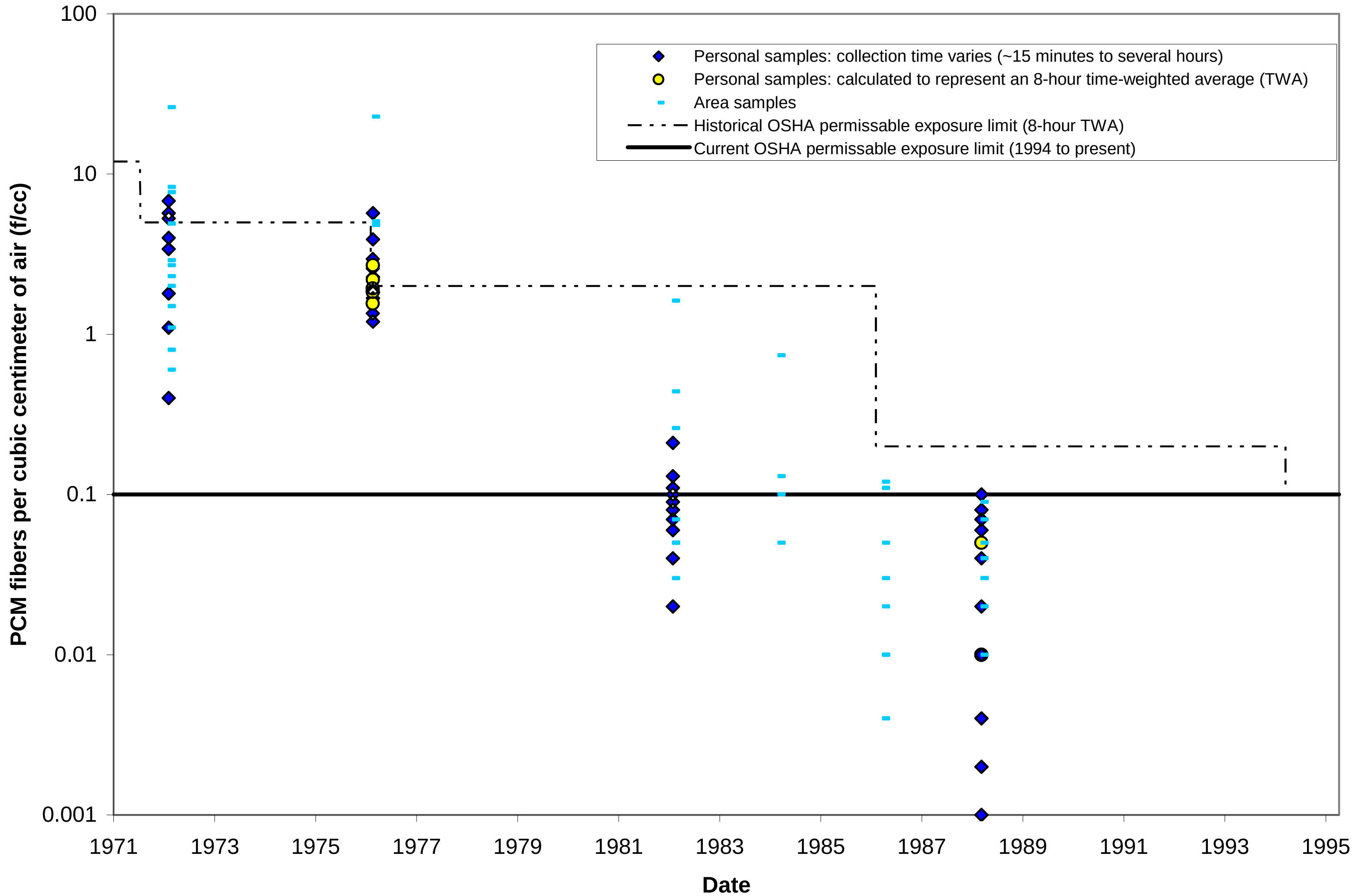


Figure 5. Vermiculite

Figure 6. Waste rock

Waste rock from vermiculite exfoliation can look like other types of rock. The only way this waste rock could be present in your yard is if someone brought it there from a vermiculite processing plant in the past. This waste rock often contains visible "bundles" or blocky fragments of asbestos that are grayish-white and about the size of a grain of rice.

Figure 7. Airborne PCM fiber concentrations over time: personal and area sample data (N=115) at the W.R. Grace New Castle facility, New Castle, Pennsylvania*



* From W.R. Grace Industrial Hygiene Surveys, 1972–1988. Personal samples were collected within a worker's breathing zone. 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 similar to NIOSH Method 7400.

Appendix A. Definitions

Exposure pathways

An exposure pathway is the way in which an individual comes into contact with a contaminant. An exposure pathway consists of the following five elements: (1) a *source* of contamination; (2) a *medium* such as air or soil through which the contaminant is transported; (3) a *point of exposure* where people can contact the contaminant; (4) a *route of exposure* by which the contaminant enters or contacts the body; and (5) a *receptor population*. A pathway is considered **complete** if all five elements are present and connected. A p**otential** exposure pathway indicates that exposure to a contaminant could have occurred in the past, could be occurring currently, or could occur in the future. A potential exposure exists when information about one or more of the five elements of an exposure pathway is missing or uncertain. An **incomplete** pathway is missing one or more of the pathway elements and it is likely that the elements were never present and are not likely to be present at a later point in time. An **eliminated** pathway was a potential or completed pathway in the past, but has had one or more of the pathway elements removed to prevent present and future exposure.

Public health hazard categories

ATSDR uses public health hazard categories to describe whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are defined as follows.

No public health hazard

A category used in ATSDR's assessments for sites where people have never been and will never be exposed to harmful amounts of site-related substances.

No apparent public health hazard

A category used in ATSDR's assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

Indeterminate public health hazard

The category used in ATSDR's assessments documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Public health hazard

A category used in ATSDR's assessments for sites that pose a public health hazard because of long-term exposure (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Urgent public health hazard

A category used in ATSDR's assessments for sites where short-term exposure (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Appendix B. Asbestos overview

Asbestos is a general name applied to a group of silicate minerals consisting of thin, separable fibers in a parallel arrangement. Asbestos minerals fall into two classes, serpentine and amphibole. Serpentine asbestos has relatively long and flexible crystalline fibers; this class includes chrysotile, the predominant type of asbestos used commercially. Fibrous amphibole asbestos minerals are brittle and have a rod- or needle-like shape. Amphibole minerals regulated as asbestos by OSHA include five classes: crocidolite, amosite, and the fibrous forms of tremolite, actinolite, and anthophyllite. Other unregulated amphibole minerals, including winchite, richterite, and others, can also exhibit fibrous asbestiform properties [1].

Asbestos fibers do not have any detectable odor or taste. They do not dissolve in water or evaporate into the air, although individual asbestos fibers can easily be suspended in the air. Asbestos fibers do not move through soil. They are resistant to heat, fire, and chemical and biological degradation. As such, they can remain virtually unchanged in the environment over long periods of time.

Vermiculite that was mined in Libby, Montana, contains amphibole asbestos, with a characteristic composition including tremolite, actinolite, richterite, and winchite; this material will be referred to as Libby asbestos. The raw vermiculite ore was estimated to contain up to 26% Libby asbestos as it was mined [2]. For most of the mine's operation, Libby asbestos was considered a byproduct of little value and was not used commercially. The mined vermiculite ore was processed to remove unwanted materials and then sorted into various grades or sizes of vermiculite that were then shipped to sites across the nation for expansion (exfoliation) or use as a raw material in manufactured products. Samples of the various grades of unexpanded vermiculite shipped from the Libby mine contained 0.3-7% fibrous tremolite-actinolite (by mass) [2].

The following sections provide an overview of several concepts relevant to the evaluation of asbestos exposure, including analytical techniques, toxicity and health effects, and the current regulations concerning asbestos in the environment.

Methods for Measuring Asbestos Content

A number of different analytical methods are used to evaluate asbestos content in air, soil, and other bulk materials. Each method varies in its ability to measure fiber characteristics such as length, width, and mineral type. For air samples, fiber quantification is traditionally done through phase contrast microscopy (PCM) by counting fibers with lengths micrometers (>5 µm) and with an aspect ratio (length:width) greater than 3:1. This is the standard method by which regulatory limits were developed. Disadvantages of this method include the inability to detect fibers <0.25 µm in diameter and the inability to distinguish between asbestos and non-asbestos fibers [1].

Asbestos content in soil and bulk material samples is commonly determined using polarized light microscopy (PLM), a method that uses polarized light to compare refractive indices of minerals and can distinguish between asbestos and non-asbestos fibers and between different types of asbestos. The PLM method can detect fibers with lengths greater than ~1 µm, widths greater than ~0.25 µm, and aspect ratios (length to width ratios) of greater than 3. Detection limits for PLM methods are typically 0.25-1% asbestos.

Scanning electron microscopy (SEM) and, more commonly, transmission electron microscopy (TEM) are more sensitive methods that can detect smaller fibers than light microscopic techniques. TEM allows the use of electron diffraction and energy-dispersive x-ray methods, which give information on crystal structure and elemental composition, respectively. This information can be used to determine the elemental composition of the visualized fibers. SEM does not allow measurement of electron diffraction patterns. One disadvantage of electron microscopic methods is that determining asbestos concentration in soils and other bulk materials is difficult [1].

For risk assessment purposes, TEM measurements are sometimes multiplied by conversion factors to give PCM equivalent fiber concentrations. The correlation between PCM fiber counts and TEM mass measurements is very poor. A conversion between TEM mass and PCM fiber count of 30 micrograms per cubic meter per fiber per cubic centimeter (µg/m3)/(f/cc) was adopted as a conversion factor, but this value is highly uncertain since it represents an average of conversions ranging from 5 to 150 (µg/m3)/(f/cc) [3]. The correlation between PCM fiber counts and TEM fiber counts is also very uncertain, and no generally applicable conversion factor exists for these two measurements [3]. Generally, a combination of PCM and TEM is used to describe the fiber population in a particular air sample.

Asbestos Health Effects and Toxicity

Breathing any type of asbestos increases the risk of the following health effects:

Malignant mesothelioma—cancer of the membrane (pleura) that encases the lungs and lines the chest cavity. This cancer can spread to tissues surrounding the lungs or other organs. The great majority of mesothelioma cases are attributable to asbestos exposure [1].

Lung cancer—cancer of the lung tissue, also known as bronchogenic carcinoma. The exact mechanism relating asbestos exposure with lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk of developing lung cancer [1].

Noncancer effects—these include asbestosis, scarring, and reduced lung function caused by asbestos fibers lodged in the lung; pleural plaques, localized or diffuse areas of thickening of the pleura (lining of the lung); pleural thickening, extensive thickening of the pleura which may restrict breathing; pleural calcification, calcium deposition on pleural areas thickened from chronic inflammation and scarring; and pleural effusions, fluid buildup in the pleural space between the lungs and the chest cavity [1].

Not enough evidence is available to determine whether inhalation of asbestos increases the risk of cancers at sites other than the lungs, pleura, and abdominal cavity [1].

Ingestion of asbestos causes little or no risk of non-cancer effects. However, some evidence indicates that acute oral exposure might induce precursor lesions of colon cancer and that chronic oral exposure might lead to an increased risk of gastrointestinal tumors [1].

ATSDR considers the inhalation route of exposure to be the most significant in the current evaluation of sites that received Libby vermiculite. Exposure scenarios that are protective of the inhalation route of exposure should be protective of dermal and oral exposures.

The scientific community generally accepts the correlations of asbestos toxicity with fiber length as well as fiber mineralogy. Fiber length may play an important role in clearance and mineralogy may affect both biopersistence and surface chemistry.

ATSDR, responding to concerns about asbestos fiber toxicity from the World Trade Center disaster, held an expert panel meeting to review fiber size and its role in fiber toxicity in December 2002 [4]. The panel concluded that fiber length plays an important role in toxicity. Fibers with lengths <5 µm are essentially non-toxic in terms of association with mesothelioma or lung cancer promotion. However, fibers <5 µm in length may play a role in asbestosis when exposure duration is long and fiber concentrations are high.

In accordance with these concepts, it has been suggested that amphibole asbestos is more toxic than chrysotile asbestos, mainly because physical differences allow chrysotile to break down and to be cleared from the lung, whereas amphibole is not removed and builds up to high levels in lung tissue [5]. Some researchers believe the resulting increased duration of exposure to amphibole asbestos significantly increases the risk of mesothelioma and, to a lesser extent, asbestosis and lung cancer [5]. However, OSHA continues to regulate chrysotile and amphibole asbestos as one substance, as both types increase the risk of disease [6]. EPA's Integrated Risk Information System (IRIS) assessment of asbestos also treats mineralogy (and fiber length) as equipotent.

Evidence suggesting that the different types of asbestos fibers vary in carcinogenic potency and site specificity is limited by the lack of information on fiber exposure by mineral type. Other data indicate that differences in fiber size distribution and other process differences can contribute at least as much as fiber type to the observed variation in risk [7].

Counting fibers using the regulatory definitions (see below) does not adequately describe risk of health effects. Fiber size, shape, and composition contribute collectively to risks in ways that are still being elucidated. For example, shorter fibers appear to deposit preferentially in the deep lung, but longer fibers may disproportionately increase the risk of mesothelioma [1,7]. Some of the unregulated amphibole minerals, such as the winchite present in Libby asbestos, can exhibit asbestiform characteristics and contribute to risk. Fiber diameters greater than 2–5 µm are considered above the upper limit of respirability (that is, too large to inhale) and thus do not contribute significantly to risk. Methods are being developed to assess the risks posed by varying types of asbestos and are currently awaiting peer review [7].

Current Standards, Regulations, and Recommendations for Asbestos

In industrial applications, asbestos-containing materials are defined as any material with >1% bulk concentration of asbestos [8]. It is important to note that 1% is not a health-based level, but instead represents the practical detection limit in the 1970s when OSHA regulations were created. Studies have shown that disturbing soils containing <1% amphibole asbestos, however, can suspend fibers at levels of health concern [9].

Friable asbestos (asbestos that is crumbly and can be broken down to suspendable fibers) is listed as a Hazardous Air Pollutant on EPA's Toxic Release Inventory [10]. This classification requires companies that release friable asbestos at concentrations >0.1% to report the release under Section 313 of the Emergency Planning and Community Right-to-Know Act.

OSHA's permissible exposure limit (PEL) is 0.1 f/cc for asbestos fibers with lengths >5 µm and with an aspect ratio (length:width) >3:1, as determined by PCM [6]. This value represents a time-weighted average (TWA) exposure level based on eight hours per day for a 40-hour work week. In addition, OSHA has defined an "excursion limit," which stipulates that no worker should be exposed in excess of 1 f/cc as averaged over a sampling period of 30 minutes [6]. Historically, the OSHA PEL has steadily decreased from an initial standard of 12 f/cc established in 1971. The PEL levels prior to 1983 were determined based upon empirical worker health observations, while the levels set from 1983 forward employed some form of quantitative risk assessment. ATSDR has used the current OSHA PEL of 0.1 f/cc as a reference point for evaluating asbestos inhalation exposures for past workers. ATSDR does not, however, support using the PEL for evaluating exposure for community members because the PEL was developed as an occupational exposure for adult workers.

In response to the World Trade Center disaster in 2001 and an immediate concern about asbestos levels in buildings in the area, the Department of Health and Human Services, EPA, and the Department of Labor formed the Environmental Assessment Working Group. This work group was made up of ATSDR, EPA, CDC's National Center for Environmental Health, the National Institute of Occupational Safety and Health (NIOSH), the New York City Department of Health and Mental Hygiene, the New York State Department of Health, OSHA, and other state, local, and private entities. The work group set a re-occupation level of 0.01 f/cc after cleanup. Continued monitoring was also recommended to limit long-term exposure at this level [11]. In 2002, a multi-agency task force headed by EPA was specifically formed to evaluate indoor environments for the presence of contaminants that might pose long-term health risks to residents in Lower Manhattan. The task force, which included staff from ATSDR, developed a health-based benchmark of 0.0009 f/cc for indoor air. This benchmark was developed to be protective under long-term exposure scenarios, and it is based on risk-based criteria that include conservative exposure assumptions and the current EPA cancer slope factor. The 0.0009 f/cc benchmark for indoor air is primarily applicable to airborne chrysotile fibers. [12]

NIOSH set a recommended exposure limit of 0.1 f/cc for asbestos fibers longer than 5 µm. This limit is a TWA for up to a 10-hour workday in a 40-hour work week [13]. The American Conference of Government Industrial Hygienists (ACGIH) has also adopted a TWA of 0.1 f/cc as its threshold limit value [14].

EPA has set a maximum contaminant level (MCL) for asbestos fibers in water of 7,000,000 fibers longer than 10 µm per liter, based on an increased risk of developing benign intestinal polyps [15]. Many states use the same value as a human health water quality standard for surface water and groundwater.

Asbestos is a known human carcinogen. Historically, EPA has calculated an inhalation unit risk for cancer (i.e., cancer slope factor) of 0.23 per f/cc of asbestos [3]. This value estimates additive risk of lung cancer and mesothelioma using a relative risk model for lung cancer and an absolute risk model for mesothelioma.

This quantitative risk model has significant limitations. First, the unit risks were based on measurements with phase contrast microscopy and therefore cannot be applied directly to measurements made with other analytical techniques. Second, the unit risk should not be used if the air concentration exceeds 0.04 f/cc because above this concentration the slope factor might differ from that stated [3]. Perhaps the most significant limitation is that the model does not consider mineralogy, fiber size distribution, or other physical aspects of asbestos toxicity. EPA is in the process of updating their asbestos quantitative risk methodology given the limitations of the current assessment and the knowledge gained since it was implemented in 1986.

Appendix B References

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Appendix C. Exposure pathways for vermiculite processing facilities*

Pathway	Environmental medium and transport mechanism	Point of exposure	Route of exposure	Exposed population	Time
Occupational	Suspension of Libby asbestos fibers or contaminated dust into air during materials transport and handling operations or during processing operations	On the site	Inhalation	Former workers	Past
	Suspension of Libby asbestos fibers into air from residual contamination inside former processing buildings	Inside former processing buildings	Inhalation	Current workers	Present, Future
Household Contact	Suspension of Libby asbestos fibers into household air from clothing or body of workers who did not shower or change clothes after work	Workers' homes	Inhalation	Former and/or current workers' families and other household contacts	Past, present, future
Waste Piles	Suspension of Libby asbestos fibers into air by playing in or otherwise disturbing piles of vermiculite or waste rock	Waste piles on the site	Inhalation	Community members, particularly children	Past, present, future
On-site Soil	Suspension of Libby asbestos fibers into air from disturbing contaminated material remaining in on-site soils (residual soil contamination, buried waste)	At areas of remaining contamination at or around the site	Inhalation	Current on-site workers, contractors, community members	Past, Present, future
Ambient Air	Stack emissions and fugitive dust from plant operations into neighborhood air	Neighborhood around site	Inhalation	Community members, nearby workers	Past
Residential Outdoor	Suspension of Libby asbestos fibers into air by disturbing contaminated vermiculite brought off the site for personal uses (gardening, paving driveways, traction, fill)	Residential yards or driveways	Inhalation	Community members	Past, present, future
Residential Indoor	Suspension of household dust containing Libby asbestos from plant emissions or waste rock brought home for personal use	Residences	Inhalation	Community members	Past, present, future
Consumer Products	Suspension of Libby asbestos fibers into air from using or disturbing insulation or other consumer products containing Libby vermiculite.	At homes where Libby asbestos-contaminated products were/are present	Inhalation	Community members, contractors, and repairmen	Past, present, future

* The contaminant source for all pathways is asbestos-contaminated vermiculite from Libby, Montana.