Health Consultation

Former California Zonolite/W.R. Grace & Company Site

5440 West San Fernando Road
Glendale, Los Angeles County, California
USEPA Facility ID: CAN000905898 and CAN000905894

June 14, 2007

Prepared by

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

Foreword: ATSDR's National Asbestos Exposure Review

Vermiculite, a naturally occuring 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 around the United States 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 local, state, and federal 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 exposures 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 beyond the scope of this project. Information for consumers of vermiculite products has been developed by the U.S. Environmental Protection Agency (USEPA), 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 based on the following criteria.

- USEPA mandated further action at the site based upon 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 more than 200 other 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

ATSDR evaluated the former California Zonolite/W.R. Grace & Company site in Glendale, California, because more than 120,000 tons of asbestos-contaminated vermiculite were shipped to the site and expanded 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 California Zonolite/W.R. Grace & Company facility operated from 1950 to 1977. The site consists of 2.75 acres of land on the north side of greater Los Angeles. Land use around the site is commercial, light industrial, and residential. The closest residential area is located 500 yards to the east. 1990 census data indicate 1,748 people lived within 1 mile of the site during the decade after vermiculite processing ceased.

While the facility was operating, workers at the facility and members of their households were exposed to asbestos from the processing and handling of asbestos-contaminated vermiculite and waste rock. Sufficient site- and process-specific information is available to consider these exposures a public health hazard. On the basis of the information available, ATSDR estimates that from 70 to 150 former workers were exposed during the time the plant operated.

Community members who lived or worked near the Glendale facility in the past could have been exposed to Libby asbestos in a variety of ways. Insufficient information is available to verify community exposure or to quantify the magnitude, frequency, or duration of the exposure. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached the downwind residential area from 1950 to 1977 and (2) stockpiles of waste rock at the site that may have been accessible to community members, especially children.

Most community members who live or work near the site now are not being exposed to asbestos from the site. The primary 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 now to Libby asbestos through direct contact with waste rock taken from the site in the past.

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. Because of existing data gaps and limitations in the science related to the type of asbestos at these sites, the risk of current or future health impacts for exposed populations is difficult to quantify.

The California Division of Health Services (CDHS) completed a review of existing health statistics (cancer registry and death certificate data) for the community surrounding the site. For the study populations and time periods included in this review, CDHS found no evidence of increased incidence or mortality rates for asbestos-related diseases. The health statistics review is useful as a screening tool to detect significant excesses of asbestos-related disease or mortality.

However, because of the limitations of this type of analysis, the lack of evidence of increased asbestos-related disease or mortality does not establish that the surrounding community was not exposed to Libby asbestos from the site.

At this site, where little can be done about past exposures and their resulting health effects, promoting awareness and offering health education to exposed and potentially exposed populations is an important intervention strategy. Health messages should be structured to facilitate self-identification and to encourage exposed individuals to either inform their regular physician or consult a physician with expertise in asbestos-related lung disease. Health care provider education in this community would facilitate surveillance and improved recognition of nonoccupational risk factors that can contribute to asbestos-related diseases.

Background

ATSDR evaluated the former California Zonolite/W.R. Grace & Company site in Glendale, California, because a large amount of vermiculite contaminated with amphibole asbestos was processed at the site by exfoliation. Based on available invoice data, the facility received more than 120,000 tons of vermiculite between 1967 and 1977 (USEPA, unpublished data, 2001).[1]

California Zonolite started processing vermiculite at the site in 1950. In 1966, W.R. Grace and Company (W.R. Grace) purchased the operation and continued vermiculite exfoliation at the site until 1977. Internal company memos indicate the facility shut down in 1977 (USEPA, unpublished data, 2001).

The Glendale facility produced expanded vermiculite for use as lightweight aggregate in concrete and plaster, loose fill insulation for attics and masonry walls, and as an ingredient in spray-applied fireproofing for steel building structures (USEPA, unpublished data).[2] The Monokote 3 fireproofing product was formulated with 10% to 19% chrysotile asbestos as an additive. Monokote 3 production was discontinued at all W.R. Grace facilities by July 5, 1973 (USEPA, unpublished data).

Two separate businesses, a tool manufacturing company and a chemical company, currently operate at the site. Some of the buildings that are used now by these companies were used for vermiculite processing and handling in the past.

Site description and setting

The Glendale site is located at 5440 San Fernando Road, within the City of Glendale, on the north side of greater Los Angeles, California (Figure 1). The site consists of 2.75 acres of land zoned for commercial/industrial use (Figure 2). Much of the site is paved.

Current land use for the area around the site is a mixture of commercial, industrial, and residential. Residential areas located north and east of the site are visible in aerial photographs dating back to 1940, before the site was used for vermiculite processing [1]. The closest residential area is 500 yards to the east (Figure 3). U.S. Census records for census tracts within several miles of the site indicate that most of the homes in the area surrounding the site were constructed before 1979 [2]. However, more than 75% of the homeowners in these census tracts moved into their current home in the 1980s and 1990s [2]. This broad analysis of available U.S. Census data indicates that many of the people who live near the site now did not reside there when the facility processed vermiculite. 1990 census data indicate 1,748 people lived within 1 mile of the site during the decade after vermiculite processing ceased (Figure 1).

The National Weather Service characterizes the climate in Los Angeles as moderate, with a dry summer and a rainy winter. The average annual rainfall in downtown Los Angeles is 14.77 inches [3]. A large part of the annual rainfall comes in the form of storms during the rainy season. The annual average high temperature for the city is 75 degrees Fahrenheit, while the

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

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

average low temperature is 57 degrees Fahrenheit. Meteorological data from the Los Angeles International Airport suggest that the predominant wind direction for the area is from the west and southwest (Figure 4). The airport is 27 miles southwest 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 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."[4]

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 Glendale facility and to other processing facilities throughout the country. Before milling, the raw vermiculite from the Libby mine contained up to 26% asbestos [5]. The various grades of milled vermiculite shipped from Libby contained fibrous amphibole asbestos at concentrations ranging from 0.3% to 7.0% [5].

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, accordion like nuggets (Figure 5) [4]. 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% (USEPA, unpublished data; J. Kelly, Minnesota Department of Health, personal communication, 2002).

The summary of vermiculite exfoliation operations presented in the following paragraphs was derived from historical BOM reports [6, 7] and company documents from W.R. Grace (USEPA, unpublished data, 2000). W.R. Grace owned and operated the Libby mine and several dozen vermiculite exfoliation facilities, including the Glendale facility, from 1963 to the early 1990s. Based on our research, ATSDR expects the Glendale facility operations to be similar to those described in the following paragraphs.

In general, vermiculite exfoliation facilities were small-scale operations employing less 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), equipment maintenance, and general housekeeping.

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 USEPA Clean Air Act amendments, W.R. Grace submitted information to USEPA in May of 1973 indicating that 19 of their 31 exfoliation facilities, including the Glendale facility, had particulate and asbestos emission control equipment that was compliant with the regulations (USEPA, 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 [8], W.R. Grace initiated employee monitoring and various process design changes to achieve compliance with the OSHA regulations (USEPA, unpublished data).

At some exfoliation facilities, respiratory protection (e.g., dust masks, various types of respirators) was periodically documented for certain job categories in industrial hygiene reports dating back to the early 1970s (USEPA, unpublished data). Information is not available to evaluate the use or effectiveness of this respiratory equipment in reducing workers exposure 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 (USEPA, 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 (USEPA, 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 (USEPA, unpublished data)[9]. Prior to that, 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 at the site, these stockpiles were accessible to the public, and children played in them [10, 11]. At one exfoliation facility, workers and nearby community members were encouraged to take waste rock home for personal use [10].

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 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 [4].

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 [4]. In this report, the terms Libby asbestos and amphibole asbestos 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 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 [12].

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 ingestion and dermal exposures routes may exist, health risks from these exposures are very low compared to health risks from the inhalation route [12]. 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 [12].
- *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 [12].
- *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) [12].

The latency period for noncancer respiratory effects is usually 15–40 years from the time of initial exposure to asbestos. For lung cancer and mesothelioma, the latency periods are generally 20–30 years or more [12, 13].

Numerous studies of occupationally exposed workers conclusively demonstrate that inhalation of asbestos can increase the risk of mesothelioma, lung cancer, and various noncancer health effects [12]. Several studies have documented health impacts consistent with asbestos-related disease in workers and others associated with the Libby mine [14-19]. Asbestos-related health impacts to workers associated with vermiculite exfoliation facilities have also been documented [20, 21].

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 [12]. 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. 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 [12, 22, 23]. Short amphibole fibers (less than 5 micrometers) are thought to be less important in inducing carcinogenic effects, but they may play a larger role in increasing the risk of noncancer effects such as asbestosis [24]. The fibrous forms of amphibole asbestos are potentially more toxic than the commonly encountered serpentine fibers (chrysotile) [12, 22, 25].

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 [21]. 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 USEPA 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 and dust, outdoor soil, and bulk material sampling results from USEPA’s site investigation in 2001 [26].

USEPA assembled and summarized W.R. Grace invoices for shipments of vermiculite from the Libby mine to vermiculite 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 USEPA’s summary of invoices to estimate vermiculite tonnage figures for the Glendale facility (USEPA, 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 Glendale site from a database of W.R. Grace documents. USEPA obtained this document database, comprised of approximately 2.5 million electronic image files, during the investigation of the Libby mine. USEPA Region 8 obtained through legal means 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.

ATSDR obtained several site-specific documents from W.R. Grace containing historical operational and environmental data. These data consisted of industrial hygiene reports, confirmation air samples collected by W.R. Grace after they had closed and cleaned the site, and information concerning waste disposal. Other sources of data used for evaluating the site include U.S. Census data, aerial photographs, and site visits by ATSDR and USEPA.

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 evaluating actual or assumed exposures based on calculating the risk of potential health impacts was not possible given the limitations in available data.

Using knowledge gained from investigations in Libby, Montana, and at a few early investigations at vermiculite exfoliation facilities, ATSDR identified several likely pathways for occupational and community exposure to asbestos at vermiculite exfoliation 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 exposures to amphibole asbestos. These limitations necessitate that ATSDR use a conservative approach to public health decision-making for the site.

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 [8]. 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” [8]. 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 [8].

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 [27]. A risk-based comparison value of 0.0009 f/cc for asbestos in indoor air was developed to be protective under long-term residential exposure scenarios [28]. All three exposure values (i.e., the OSHA PEL, the two World Trade Center community guidance values) are primarily applicable to airborne chrysotile asbestos fibers that have lower toxicity than amphibole 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

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

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 equal to or greater than 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. Federal standards regulate materials that contain more than 1% asbestos [29, 30]; therefore, the 1% level has been used as an action level for soil remediation activities at a number of sites. USEPA and ATSDR recognize that this 1% standard 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 [31]. 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 [32, 33].

Health statistics review

Data sources and methods used for evaluating existing health statistics for the community surrounding the Glendale site are discussed in Appendix D.

Results

A summary of the exposure pathway evaluations for the Glendale site is presented in Table 2. The findings for each of the pathways are discussed in the following paragraphs. The results of the health statistics review are included in Appendix D.

Table 2. Summary of exposure pathway evaluations for the Glendale 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 (1950–1977)**	**Complete**	**Public health hazard**
	On-site workers inhaling Libby asbestos from residual contamination inside former processing buildings or in on-site soil (residual contamination, buried waste)	Past (1977–2002)	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
Household Contact	Household contacts inhaling Libby asbestos brought home on workers' clothing, shoes, and hair	**Past (1950–1977)**	**Complete**	**Public health hazard**
		Past (1977–2002)	Potential	No apparent public health hazard
		Present/ 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 piles of contaminated vermiculite or waste rock at the site	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	Potential	No apparent 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: 1950–1977 timeframe)

Former workers were exposed to airborne Libby asbestos in and around the facility during handling and processing of vermiculite during 1950–1977. Personal and area sampling results for workers at the facility indicate airborne fiber levels in the range of 0.1 f/cc to 10 f/cc in the 1970s (Figure 7). Personal samples, typically collected within a worker's breathing zone, were associated with specific workers. Most of the area sampling was conducted at locations in the exfoliation process where fibers were likely to be released (e.g., the furnace baghouse, the furnace stoner deck where waste rock and expanded product were separated, the waste rock hopper) (USEPA, unpublished data). Sample collection time varied from 15 minutes to several hours; some sample results represent 8-hour time-weighted averages (Figure 7).

Although no sampling data are available from 1950 to 1971, airborne fiber levels during this period were probably in the same range or higher than the levels documented in 1972 (1 f/cc to 10 f/cc). Measured airborne fiber levels within the Glendale facility (and at other vermiculite exfoliation facilities for which we have more data) decreased throughout the 1970s, probably as a result of W.R. Grace's efforts to comply with federal OSHA regulations promulgated in 1971 to protect workers from occupational exposure to asbestos[4] (USEPA, unpublished data). Asbestos exposure levels for workers could have been much higher in the 1950s and 1960s prior to OSHA regulations. Asbestos exposures 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 frequency and duration of former worker exposures varied depending on their job assignment, facility operation schedule, and period of employment. The Glendale facility had 2 exfoliation furnaces in the 1960s and added a third around 1964. At times they exfoliated vermiculite 24 hours a day (USEPA, unpublished data). The facility reportedly employed 19 people in 1966 (USEPA, unpublished data). The length of employment for workers at the Glendale facility is unknown.

California Zonolite and W.R. Grace employees may have worn masks for respiratory protection (USEPA, unpublished data). Information is not available to evaluate the overall effectiveness of any respiratory equipment used to reduce worker exposure to asbestos fibers. 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.

Vermiculite exfoliation was reportedly a dusty operation. 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. Workers could have been exposed to Libby asbestos outside the facility as well. Fugitive emissions from loading, unloading, or transferring bulk vermiculite or waste rock resulted in outdoor airborne asbestos fiber releases. Information provided to USEPA 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 [34]. Stack emissions from the furnaces and the Monokote mixer also contributed to outdoor fiber releases, particularly before air pollution control equipment was installed.

Various non-W.R. Grace workers probably visited the Glendale facility periodically to haul waste rock away from the facility, purchase products, pick up products for delivery, or provide services (e.g., construction and electrical services, equipment maintenance). Data available from other facilities indicate that waste haulers may have been exposed to asbestos as they loaded and unloaded waste rock (USEPA, unpublished data).

The non-W.R. Grace workers on the site may have been exposed to airborne asbestos in and around the Glendale facility, but the frequency and duration of the exposure was likely very low. The intensity, frequency, and duration of the exposure to waste haulers and construction workers may have been higher than the exposure of other non-W.R. Grace workers. All of these on-site

[4] 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).

workers were exposed much less frequently and for much shorter durations than the full-time workers at the W.R. Grace facility.

Occupational pathway (past: 1977–2002 timeframe)

W.R. Grace stopped exfoliating vermiculite at the Glendale facility in 1977. Other businesses have occupied the site since that time. Most sources of Libby asbestos have been eliminated from the site, including vermiculite and waste rock stockpiles. USEPA sampling in 2001 indicated areas of residual asbestos remained in some onsite buildings and onsite soils (soil sample results contained up to 7% asbestos; dust sample results contained up to 3,471,238 structures per centimeter of tremolite/actinolite fibers). Sampling locations and analytical results are described in detail in a report issued by USEPA [26].

Under USEPA oversight, the site owner remediated areas of residual asbestos in April and May of 2002 [35]. Workers at the site could have been exposed to residual asbestos fibers in buildings or outside soil during 1977–2002. However, insufficient information is available to characterize these exposures.

Occupational pathway (present/future timeframe)

The areas of residual Libby asbestos identified by USEPA at the Glendale site were remediated in April and May of 2002. The initial remediation, confirmation sampling, and follow up remediation of certain areas of soil with residual contamination were conducted under USEPA oversight [35]. Some areas where contaminated soil was excavated were backfilled with clean material and then paved. On May 29, 2002, USEPA performed a final inspection of the site and subsequently issued a letter of compliance to the site owner [35].

Household contact pathway (past: 1950–1977 timeframe)

Household contacts of former workers were likely exposed to airborne Libby asbestos unintentially brought home on the workers' clothing, shoes, and hair. 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. Members of the households of former W.R. Grace workers were exposed to Libby asbestos fibers brought home on the workers' clothing, shoes, and hair 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 the 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 [36, 37].

Household contact pathway (past: 1977–2002 timeframe)

Workers at the site may have been exposed to residual Libby asbestos associated with vermiculite processing buildings or soil on the site. These workers may have brought home low concentrations of asbestos on their clothing, hair, or shoes. Data are not available to characterize potential secondary exposures to household members who had contact with these workers or their clothing. However, this secondary exposure to household members was likely low because the source concentrations were low at the facility and transport and re-suspension processes (fibers transported home on workers or their clothing, fibers re-suspended into the air at home) would reduce the airborne concentrations even further.

Household contact pathway (present/future timeframe)

The areas of residual Libby asbestos identified by USEPA at the Glendale site were remediated in April and May of 2002. On the basis of available sampling and remediation data, current and future worker exposure pathways are considered eliminated.

Community pathways (past timeframe)

Community members who lived or worked around the Glendale facility from 1950 to 1977 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. Available information is insufficient to reconstruct the magnitude, frequency, or duration of these community exposures.

According to data from the nearest meteorological station, the predominant wind direction is from the west and southwest (Figure 4), toward the residential areas located east and northeast of the Glendale site (Figures 1–3). On the basis of aerial photographs from the area, these residential areas were established as early as 1940, before vermiculite exfoliation began at the Glendale facility [1]. Community members and area workers located downwind (east and northeast) of the facility could have been exposed to Libby asbestos fibers released into the ambient air from fugitive emissions or from furnace stack emissions generated while the facility was operating.

Fugitive emissions from loading, unloading, or transferring bulk vermiculite or waste rock resulted in airborne asbestos fiber releases in areas around the facility. Stack emissions from the furnaces and the Monokote mixer also contributed to outdoor fiber releases. The Glendale facility received notice of air pollution violations in 1960 and 1970 (USEPA, unpublished data). In 1972, a formal complaint signed by 7 community members was submitted to the Los Angeles County Air Pollution Control District alleging that dust from the facility was a public nuisance, settling on their roof(s) and damaging their cars (USEPA, unpublished data).

The concentrations of airborne asbestos fibers in outdoor air around the facility due to fugitive and stack emissions were likely much higher prior to the 1970s. 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 (USEPA, unpublished data). Particulates captured by the filters in the control equipment reportedly contained 1%–3% friable Libby asbestos (USEPA, unpublished data).

The exposure pathway for community members (particularly children) playing in or otherwise disturbing on-site piles of contaminated vermiculite, waste rock, or on-site soil at the facility in the past is considered to be 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 [10, 11, 38].

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 [10]. Insufficient information is available to determine whether this happened at the Glendale facility during the time vermiculite was processed there. 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 Glendale facility from plant emissions or from waste rock brought home for personal use. Insufficient information is available concerning the level of indoor residential contamination that may have resulted from past air emissions and community use of waste rock. Indoor residential exposure to Libby asbestos fibers in the past is an indeterminate 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 exposure to ambient air emissions and exposure to on-site vermiculite and waste rock piles, have been eliminated because the facility is no longer exfoliating vermiculite.

Exposure of individuals to vermiculite or waste rock taken home from the facility in the past for personal use as fill material, driveway surfacing, or as a soil amendment is a potential exposure pathway. This material could still be a source of exposure today. If the asbestos-containing material is covered (e.g., with soil, grass, other vegetation) and is not disturbed, the asbestos fibers will not become airborne and will not pose a public health hazard. Insufficient information is available to determine whether people took waste rock home for personal use.

Residential indoor exposure to residual Libby asbestos from facility emissions or other 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.

Discussion

Exposure pathway evaluations

This site evaluation highlights two groups of people who experienced the most significant exposure to Libby asbestos associated with the Glendale vermiculite exfoliation facility: former employees at the facility and household contacts of these former workers. Insufficient information is available to verify or quantify several other potential exposure pathways, such as those involving community members who lived around the site in the past when the facility actively processed vermiculite.

Given the limited or nonexistent exposure data available to characterize many of the pathways associated with Libby asbestos at the Glendale site, the theoretical risk of future health impacts for the exposed populations cannot be quantified. ATSDR is working with state health department partners across the United States to review actual historical health statistics for communities around many of the facilities that processed Libby vermiculite, including the Glendale 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.

As noted previously, 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. These considerations apply to the former workers at the exfoliation facility as well as to any individuals that may have had direct contact with residual asbestos present in soil at the site or waste rock that was used in the community.

Increased health risks due to exposure to Libby asbestos are difficult to quantify, and actual asbestos-related health 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. Public health agencies should develop health messages that 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 these communities would facilitate improved surveillance and recognition of nonoccupational risk factors that can contribute to asbestos-related diseases.

Limitations

A number of site-specific limitations affect the exposure pathway evaluation and health risk characterization efforts at the Glendale 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. The available site-specific sampling results typically do not describe the mineralogy and fiber size distribution of the asbestos detected. An adequate toxicological model to evaluate the noncarcinogenic health risks of amphibole asbestos exposure does not exist. The current USEPA 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.[5] Because of these limitations, ATSDR did not conduct a quantitative assessment of the actual toxicity and potential health impacts associated with exposure at this site.

[5] 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 [21]. This draft methodology requires detailed asbestos sample characterization beyond what was generated at the Los Angeles site.

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

Health statistics review

A detailed discussion of the findings and limitations of the health statistics review for the community surrounding the Glendale facility is included in Appendix D. A protocol similar to the one used in this health statistics review identified a statistically significant excess of asbestos-related disease in the Libby, Montana, community. If the study populations around the Glendale facility were similar to the Libby community in terms of level of exposure to Libby asbestos, population mobility, and other characteristics, then this type of analysis should also be able to detect a statistically significant excess of asbestos-related disease in the community around the Glendale facility. However, as discussed in Appendix D, the study populations for the Glendale facility differ from the Libby community in ways that increase the limitations of this type of analysis. Therefore the results of the Glendale health statistics analysis may not serve as a reliable indicator of past community exposure.

Conclusions and recommendations

Former workers and their household contacts (1950 to 1977)

People who worked at the W.R. Grace Glendale facility from 1950 to 1977 were exposed to airborne levels of Libby asbestos above current occupational standards. Repeated exposure to airborne Libby asbestos at these elevated levels increased a worker's risk for asbestos-related disease and therefore posed a *public health hazard* to former employees. On the basis of available information, ATSDR estimates that from 70 to 150 former workers were exposed during the time the plant operated.

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 physician about their exposure to asbestos. If former workers or their household contacts are concerned or symptomatic, they should be see a physician who specializes in asbestos-related lung diseases.

Current or future workers and their household contacts (1977 to present/future)

After the Glendale facility ceased exfoliation vermiculite in 1977, some residual asbestos remained inside the buildings and in soil at the site. Other businesses have occupied the site since then. Employees on the site could have been exposed to residual asbestos during 1977–2002. However, information is insufficient to characterize these exposures. Exposure pathways involving these areas are considered an indeterminate public health hazard for the 1977–2002 timeframe.

Areas of residual Libby asbestos were remediated in April and May of 2002. Current (after May 2002) and future occupational exposure pathways are considered eliminated and pose *no public health hazard*.

Recommendation

- Promote awareness of potential asbestos exposure among employees that worked at the site during 1977–2002.
- Encourage these workers to inform their physician about their potential exposure to asbestos in the past.

Community members who lived near the facility (1950 to 1977)

The people in the community around the site during the time the Glendale facility processed Libby vermiculite could have been exposed to Libby asbestos fibers in a number of ways: from plant emissions; from disturbing or playing in contaminated soil or waste piles on the site; from waste rock brought home for personal use; or from indoor household dust that contained Libby asbestos from one or more outside sources. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached the downwind residential area during 1950–1977 and (2) on-site waste rock piles that may have been accessible to community members, especially children.

Insufficient information is available to determine whether these exposures occurred and, if so, how often they may have occurred, or what concentrations of airborne Libby asbestos may have been present during potential exposures. 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 exposure among community members who lived near the facility from1950 to 1977. Provide these people with easily accessible materials that will assist them in identifying their own potential for 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.

Community members who live near the site now (1977 to present)

The Glendale facility no longer processes vermiculite at the site; they stopped processing vermiculite from Libby in 1977. Many of the community exposure pathways, such as ambient emissions and disturbing or playing on on-site waste piles, have been eliminated. Some areas of residual asbestos in soil at the site were excavated and removed in 2002. These exposure pathways pose *no public health hazard* to the surrounding community members.

Currently, individuals in the community could be exposed to airborne Libby asbestos from waste rock used as fill material, for gardening, for driveway paving, or for other purposes. This exposure pathway is an *indeterminate public health hazard* because insufficient information is available to determine whether waste rock was taken off the site and 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 to identify their own potential for exposure.

Health statistics review

For the selected study populations and time periods included in the review, CDHS found no evidence of increased incidence or mortality rates for asbestos-related diseases. The health statistics review is useful as a screening tool to detect significant excesses of asbestos-related disease or mortality. However, because of the limitations of this type of analysis, the lack of evidence of increased asbestos-related disease or mortality does not establish that the surrounding community was not exposed to Libby asbestos from the site.

Public health action plan

The purpose of the public health action plan is to ensure that public health hazards are not only identified, but also addressed. The public health action plan for this site describes actions that ATSDR and/or other agencies plan to take at the site to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. ATSDR will also follow up on the plan to ensure implementation of the following public health actions:

- ATSDR and CDHS will develop and disseminate reliable and easily accessible information concerning asbestos-related health issues for exposed individuals and health care providers.
- ATSDR and CDHS 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.
- ATSDR will notify former workers for whom we have contact information and provide exposure and health information about asbestos.
- ATSDR and CDHS will notify the site owner, state and local health departments, and the local planning/permit department as appropriate to inform them of the findings and recommendations regarding the site.
- ATSDR is researching and determining the feasibility of conducting additional worker and household contact follow-up activities.

Authors, Technical Advisors

Author

Barbara Anderson, M.S., P.E.
Environmental Health Scientist
Division of Health Assessment and Consultation, ATSDR

Authors, Appendix D Health Statistics Review

Jackie Schwartz
Research Scientist
Former employee of Impact Assessment, Inc. contractor to
Environmental Health Investigations Branch, California Department of Health Services

Sumi Hoshinko
Research Scientist
Environmental Health Investigations Branch, California Department of Health Services

Marilyn Underwood, Ph.D.
Chief, Site Assessment Section
Environmental Health Investigations Branch, California Department of Health Services

Kevin Horton, MSPH
Epidemiologist
Division of Health Studies, ATSDR

ATSDR Regional Representative

Libby Vianu
Regional Representative, Region 9
Division of Regional Operations, ATSDR

Technical Reviewers

John Wheeler, Ph.D., DABT
Senior Toxicologist
Division of Health Assessment and Consultation, ATSDR

Susan Moore, M.S.
Branch Chief, Exposure Investigation and Site Assessment Branch
Division of Health Assessment and Consultation, ATSDR

References

1. Environmental Data Resources. Aerial photography print service for 5440 West San Fernando Road, Glendale, CA 90039. Historical aerial photographs from Fairchild (1927, 1940, 1956, 1965), Teledyne (1976), U.S. Geological Survey (1989). Milford, Connecticut: Environmental Data Resources, Inc.; 2004.

2. Bureau of the Census. 1990 Census. US Department of Commerce. Available at: http://www.census.gov.

3. National Weather Service (National Oceanic and Atmospheric Administration). Los Angeles/Oxnard. US Department of Commerce. Available at: http://www.wrh.noaa.gov/lox/climate/climate_intro.php. Accessed October 25, 2006.

4. US Geological Survey. Reconnaissance study of the geology of U.S. vermiculite deposits: are asbestos minerals common constituents? Denver: US Department of the Interior; May 7 2002.

5. Atkinson GR, Rose D, Thomas K, Jones D, Chatfield EJ, Going JE. Collection, analysis and characterization of vermiculite samples for fiber content and asbestos contamination. Prepared for EPA Office of Pesticides and Toxic Substances, Field Studies Branch by Midwest Research Institute. Washington DC: US Environmental Protection Agency; Sept 1982.

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

7. Remedium Group (subsidiary of W.R. Grace). Letter to Barbara Anderson (Agency for Toxic Substances and Disease Registry) from Robert R. Marriam transmitting company documents concerning air sampling/monitoring and waste disposal practices for selected expansion facilities. March 10, 2003.

8. Agency for Toxic Substances and Disease Registry. Health consultation: Western Mineral Products Site, Minneapolis, Hennepin County, Minnesota. Prepared for ATSDR by Minnesota Department of Health. Atlanta: US Department of Health and Human Services; May 2001.

9. Agency for Toxic Substances and Disease Registry. Health consultation: W.R. Grace Dearborn Plant, Dearborn, Wayne County, Michigan. Prepared for ATSDR by Michigan Department of Community Health. Atlanta: US Department of Health and Human Services; Oct 2004.

10. Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos (update). Atlanta: US Department of Health and Human Services; Sept 2001.

11. Lanphear BP, Buncher CR. Latent period for malignant mesothelioma of occupational origin. J Occup Med. 1992;34(7):718-21.

12. Amandus HE, Althouse R, Morgan WK, Sargent EN, Jones R. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part III. Radiographic findings. Am J Ind Med 1987;11(1):27–37.

13. Amandus HE, Wheeler R. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part II. Mortality. Am J Ind Med 1987;11(1):15-26.

14. Amandus HE, Wheeler R, Jankovic J, Tucker J. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part I. Exposure estimates. Am J Ind Med 1987;11(1):1-14.

15. McDonald JC, McDonald AD, Armstrong B, Sebastien P. Cohort study of mortality of vermiculite miners exposed to tremolite. British Journal of Industrial Medicine 1986;43(7):436-44.

16. Peipins LA, Lewin M, Campolucci S, Lybarger JA, Miller A, Middleton D, et al. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana, USA. Environ Health Perspect 2003;111(14):1753-9.

17. Agency for Toxic Substances and Disease Registry. Health consultation: mortality in Libby, Montana (1979-1998). Atlanta: US Department of Health and Human Services; Aug 2002.

18. Lockey JE, Brooks SM, Jarabek AM, Khoury PR, McKay RT, Carson A, et al. Pulmonary changes after exposure to vermiculite contaminated with fibrous tremolite. American Review of Respiratory Disease 1984;129(6):952-8.

19. Wright RS, Abraham JL, Harber P, Burnett BR, Morris P, West P. Fatal asbestosis 50 years after brief high intensity exposure in a vermiculite expansion plant. Am J Respir Crit Care Med April 15, 2002;165(8):1145-9.

20. US Environmental Protection Agency. Report on the peer consultation workshop to discuss a proposed protocol to assess asbestos-related risk. Prepared for EPA Office of Solid Waste and Emergency Response by Eastern Research Group, Inc. Washington DC: EPA; May 30, 2003.

21. Berman DW, Crump KS. Technical support document for a protocol to assess asbestos-related risk (final draft). Prepared for EPA Office of Solid Waste and Emergency Response. Washington DC: EPA; October 2003.

22. Agency for Toxic Substances and Disease Registry. Report on the expert panel on health effects of asbestos and synthetic vitreous fibers: the influence of fiber length. Atlanta: US Department of Health and Human Services; 2003.

23. McDonald JC, McDonald AD. Chrysotile, tremolite and carcinogenicity. Ann Occup Hyg Dec 1997;41(6):699-705.

24. US Environmental Protection Agency. Focused removal assessment report, Sunland Chemical and Harrington Tools properties, 5420-5440 West San Fernando Road, Glendale, CA. Prepared for EPA Region 9 by US Department of Transportation Volpe Center and CDM Federal Programs Corporation. San Francisco, CA: EPA Region 9; June 2001.

25. Agency for Toxic Substances and Disease Registry. World Trade Center response activities close-out report: September 11, 2001–April 30, 2003. Atlanta: US Department of Health and Human Services; May 16 2003.

26. US Environmental Protection Agency. World Trade Center indoor environmental assessment: selecting contaminants of potential concern and setting health-based benchmarks. New York City: EPA Region 2; May 2003.

27. U.S. Environmental Protection Agency: Asbestos-containing materials in schools, final rule and notice. Federal Register 1987 October 30;52:41826-41845.

28. U.S. Environmental Protection Agency: National emission standards for hazardous air pollutants; asbestos NESHAP revision. Federal Register 1990 November 20;55:48415.

29. US Environmental Protection Agency. Memorandum to Superfund National Policy Managers, Regions 1-10, from MB Cook (Director, Office of Superfund Remediation and Technology Innovation, EPA) clarifying cleanup goals and identification of new assessment tools for evaluating asbestos at Superfund cleanups. Washington DC: EPA; August 10, 2004.

30. US Environmental Protection Agency. Memorandum to P Peronard (On-Scene Coordinator, Libby Asbestos Site, EPA Region 8) from CP Weiss (Senior Toxicologist/Science Support Coordinator, Libby Asbestos Site, EPA Region 8) Amphibole mineral fibers in source materials in residential and commercial areas of Libby pose an imminent and substantial endangerment to public health. Denver: EPA; December 20, 2001.

31. US Environmental Protection Agency. Memorandum to J Ackerman (On-Scene Coordinator, EPA Region 8) from AK Miller (Senior Medical Officer and Regional Toxicologist, EPA Region 8) Endangerment Memo: health risks secondary to exposure to asbestos at former Intermountain Insulation facility at 800 South 733 West (SLC1), Salt Lake City, UT. Denver: EPA; March 24, 2004.

32. US Environmental Protection Agency. Priority review level 1: asbestos-contaminated vermiculite. Washington DC: Environmental Protection Agency; June 1980.

33. US Environmental Protection Agency. Pollution report for the Harrington Tool vermiculite site, Glendale (Los ANgeles), California. San Francisco, CA: EPA Region 9; June 3, 2002.

34. Anderson HA, Lilis R, Daum SM, Selikoff IJ. Asbestosis among household contacts of asbestos factory workers. Ann N Y Acad Sci 1979;330:387-99.

35. Powell C, Cohrssen B. Asbestos. In: Bingham E, Cohrssen B, Powell C, eds. Patty's toxicology. 5th ed.: John Wiley & Sons, Inc.; 2001.

36. Agency for Toxic Substances and Disease Registry. Health consultation: Vermiculite Northwest, Spokane, Spokane County, Washington. Prepared for ATSDR by Washington State Department of Health. Atlanta: US Department of Health and Human Services; July 2004.

Figures

Figure 1. Site location and 1990 demographic statistics, former California Zonolite/W.R. Grace & Company Site, Glendale, California

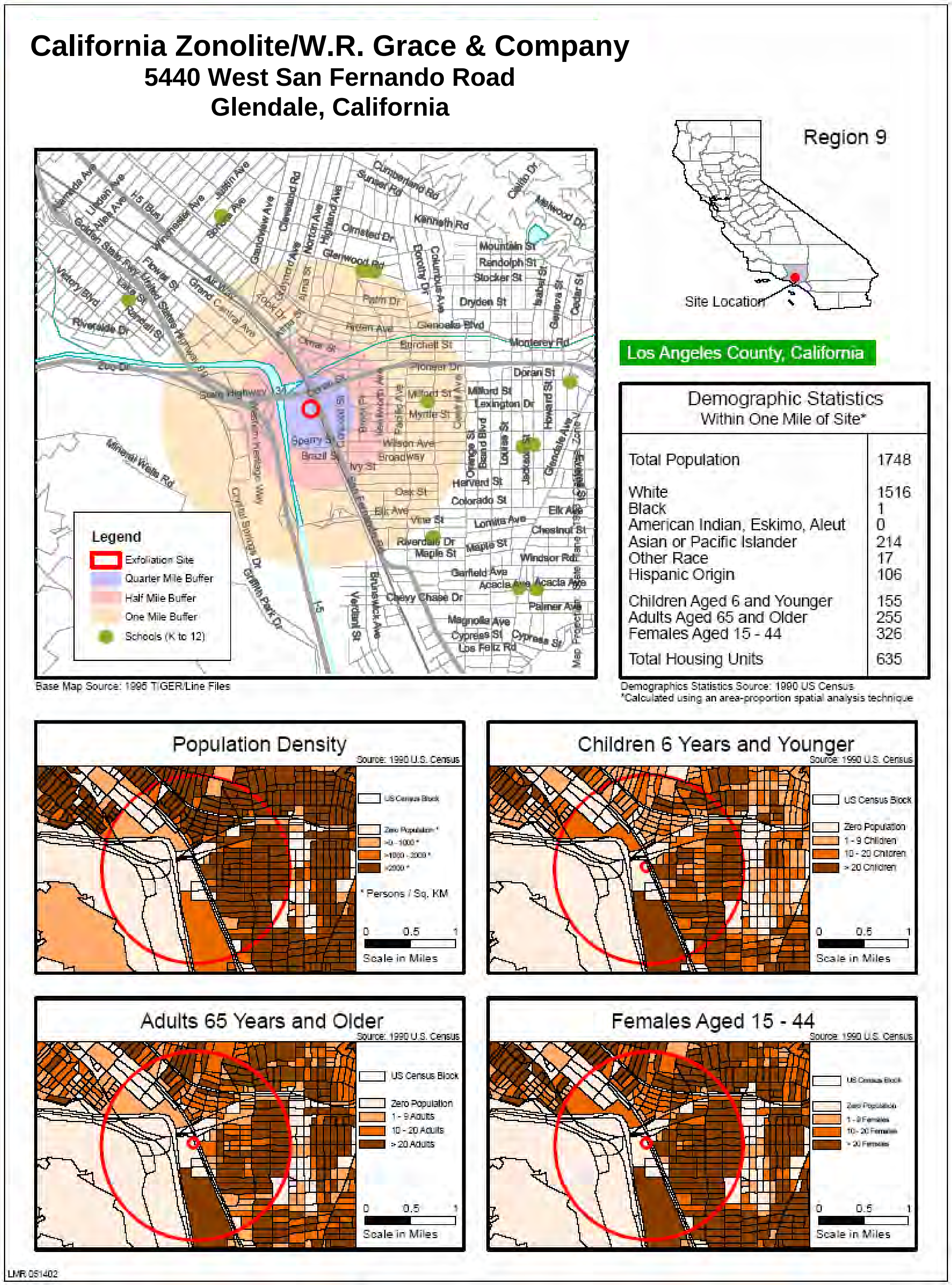
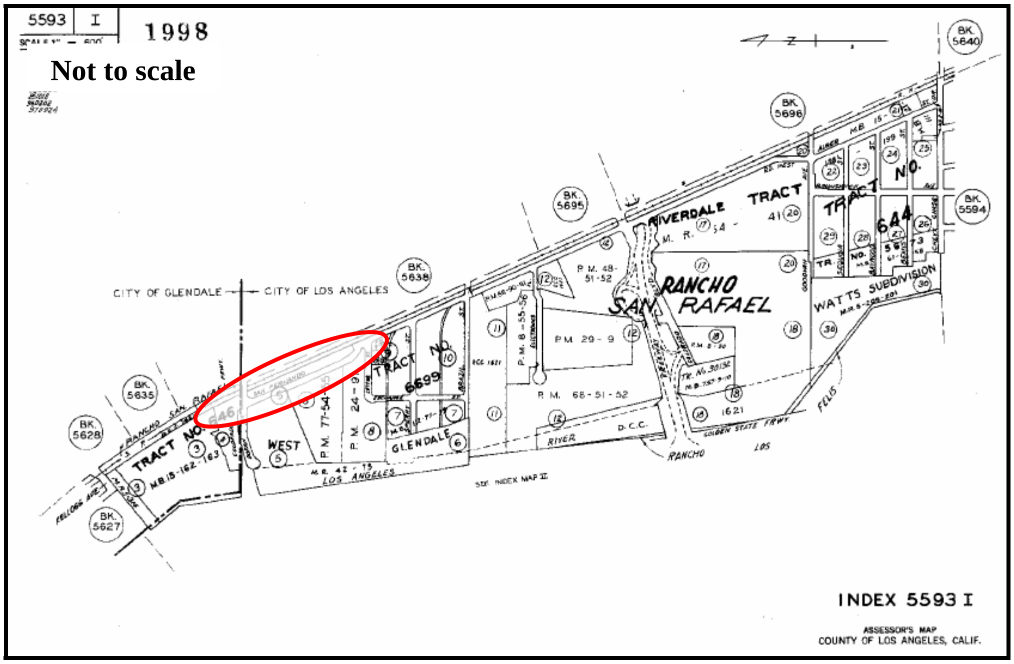
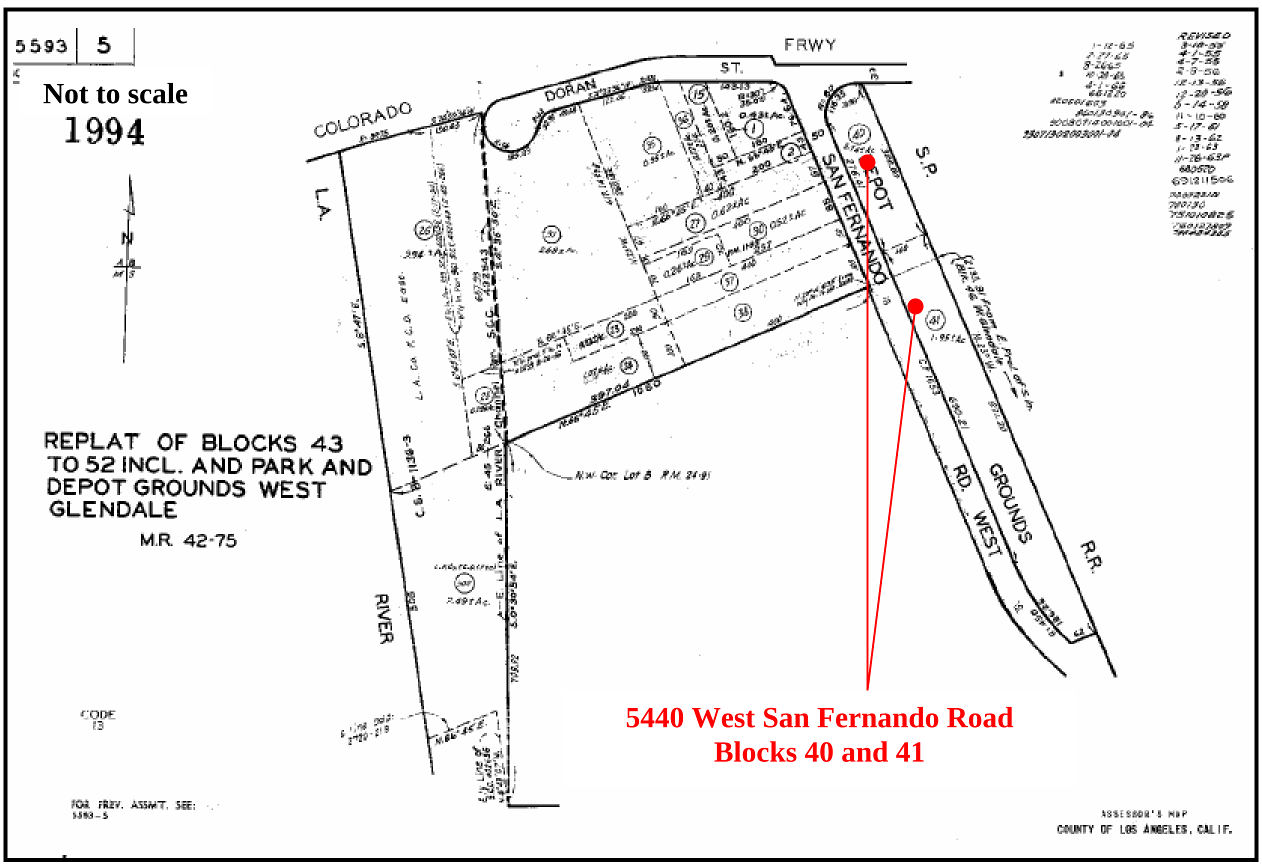


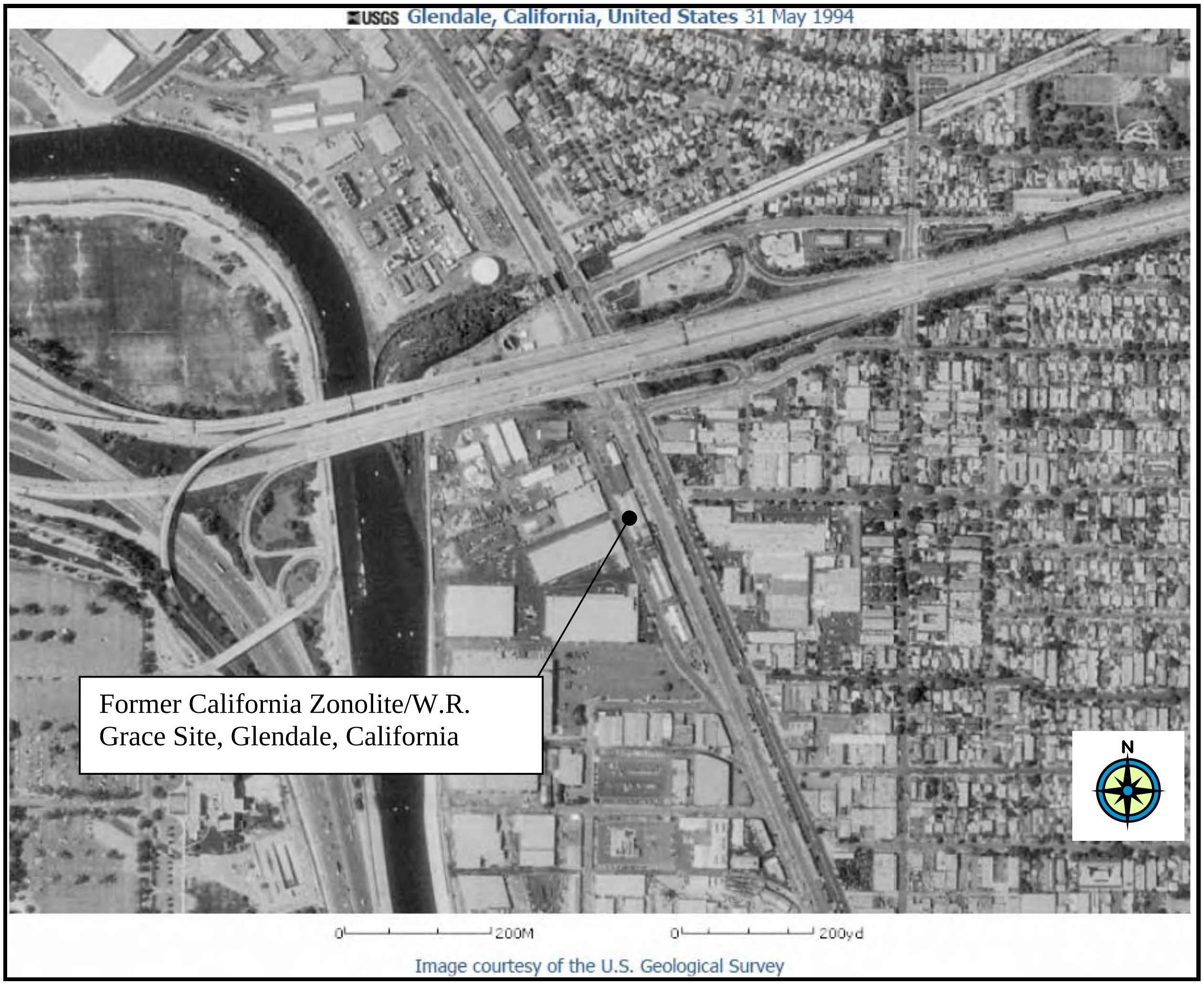
Figure 2. County of Los Angeles Tax Assessor's maps showing property boundaries*





* Available at http://lacountypropertytax.com/portal/ ; accessed on October 12, 2006.

Figure 3. Aerial photograph of the site, 1994*



* Source: U.S. Geological Survey, available online at www.terraserver-usa.com.

Figure 4: Meteorological data from the Los Angeles International Airport

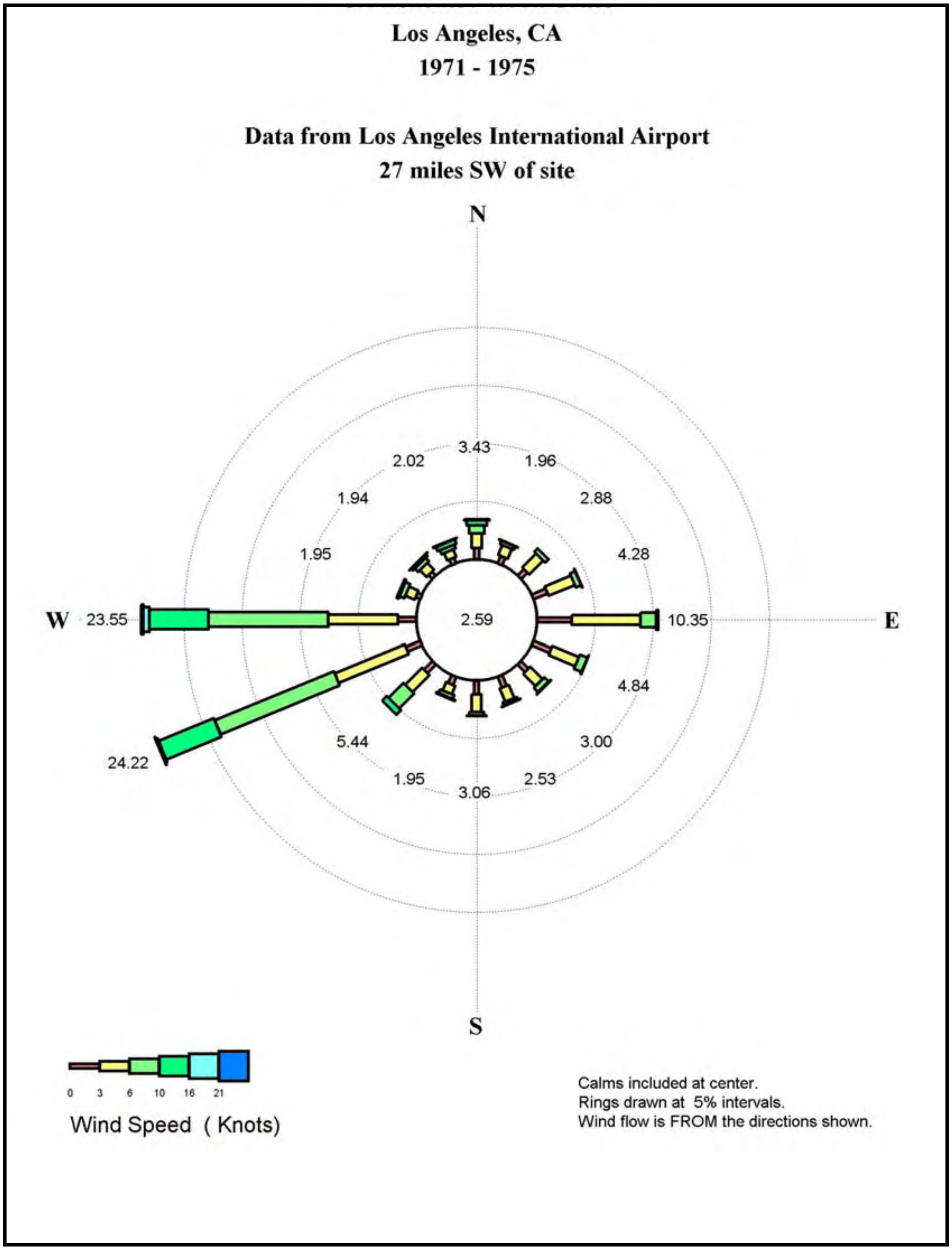
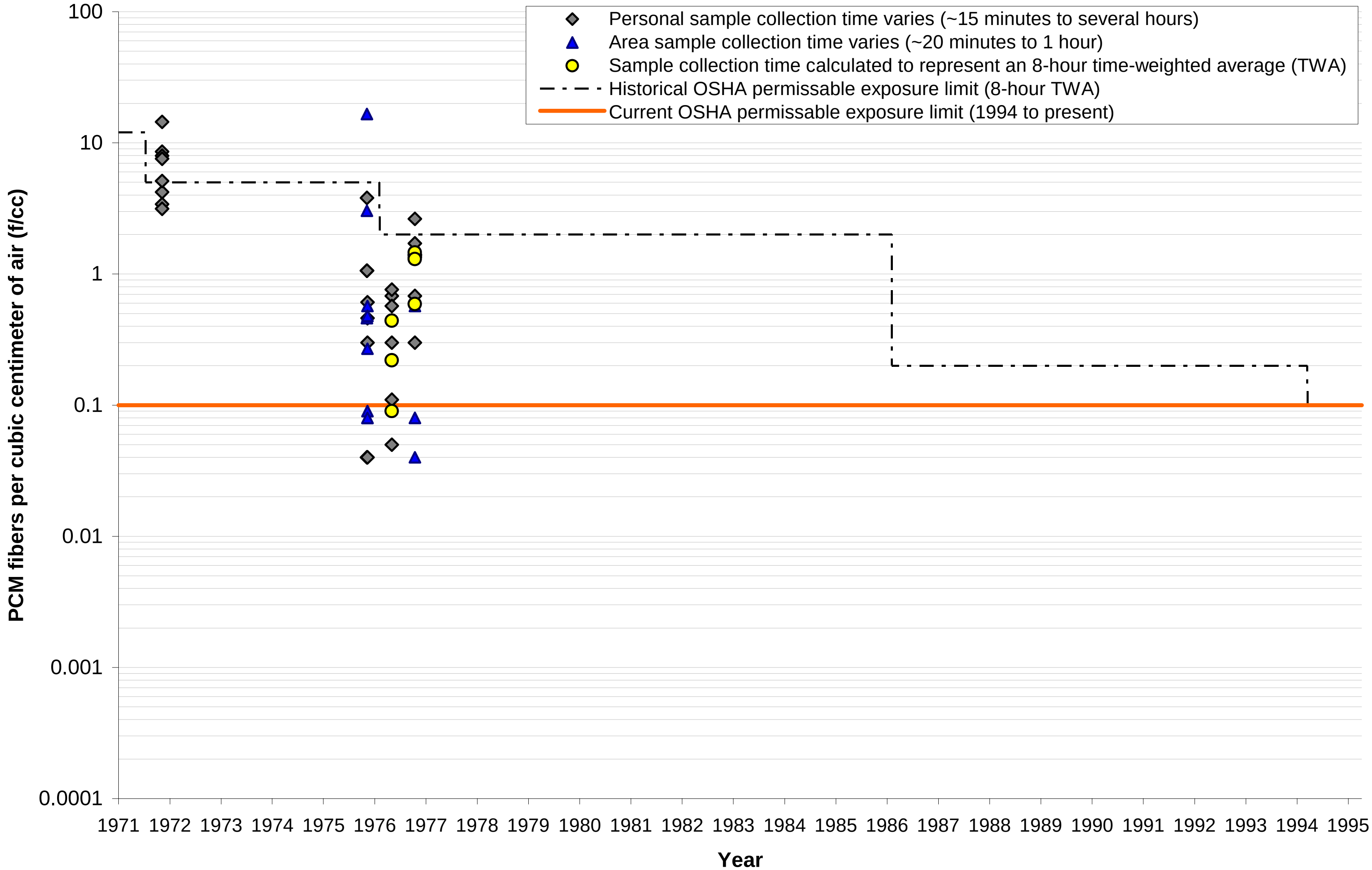


Figure 5. Vermiculite

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=50*) at the former California Zonolite/W.R. Grace & Company Site in Glendale, California



* From W.R. Grace Industrial Hygiene Surveys, 1972–1977. Personal samples were collected within a worker's breathing zone. Area samples were collected around the processing equipment or within occupied spaces in 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 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 exposures (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. Amphibole asbestos minerals are brittle and have a rod- or needle-like shape. Fibrous amphibole 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 by-product 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. A more detailed discussion of these topics will also be provided in ATSDR's upcoming summary report for the national review of vermiculite sites.

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 greater than 5 micrometers (>5 µm) and with an aspect ratio (length to 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 less than 0.25 (<0.25) µm in diameter and the inability to distinguish between asbestos and nonasbestos fibers [1].

Asbestos content in soil and bulk material samples is commonly determined using polarized light microscopy (PLM), a method which uses polarized light to compare refractive indices of minerals and can distinguish between asbestos and nonasbestos fibers and between different types of asbestos. The PLM method can detect fibers with lengths greater than approximately 1 µm (~1 µm), widths greater than ~0.25 µm, and aspect ratios (length-to-width ratios) 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 soil and other bulk material 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 because 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 vermiculite from Libby. 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. More information is needed to definitively reach this conclusion.

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]. Currently, USEPA's Integrated Risk Information System (IRIS) assessment of asbestos also currently 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 soil containing <1% amphibole asbestos, however, can suspend fibers at levels of health concern [9].

Friable asbestos (asbestos which is crumbly and can be broken down to suspendible fibers) is listed as a hazardous air pollutant on USEPA'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 8 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 on the basis of 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 exposure 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, USEPA, and the Department of Labor formed the Environmental Assessment Working Group. This work group was made up of ATSDR, USEPA, CDC's National Center for Environmental Health, the National Institute for 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 multiagency task force headed by USEPA was formed specifically 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 USEPA cancer slope factor. The 0.0009 f/cc benchmark for indoor air was formulated on the basis of chrysotile fibers and is therefore most appropriately applied 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 has also adopted a TWA of 0.1 f/cc as its threshold limit value [14].

USEPA has set a maximum contaminant level (MCL) for asbestos fibers in water of 7,000,000 fibers longer than 10 µm per liter, on the basis of 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, USEPA's IRIS model calculated an inhalation unit risk for cancer (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 the slope factor above this concentration 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. USEPA is in the process of updating their asbestos quantitative risk methodology given the limitations of the IRIS model currently used and the knowledge gained since this model was implemented in 1986.

Appendix B References

1. Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos (update). Atlanta: U.S. Department of Health and Human Services; September 2001.

2. Atkinson GR, Rose D, Thomas K, Jones D, Chatfield EJ, Going JE. Collection, analysis and characterization of vermiculite samples for fiber content and asbestos contamination. Prepared for USEPA Office of Pesticides and Toxic Substances, Field Studies Branch by Midwest Research Institute. Washington DC: US Environmental Protection Agency; Sept 1982.

3. U.S. Environmental Protection Agency. Integrated risk information system (for asbestos). Accessed on July 31, 2002, at: http://www.epa.gov/iris/subst/0371.htm.

4. Agency for Toxic Substances and Disease Registry. Report on the expert panel on health effects of asbestos and synthetic vitreous fibers: the influence of fiber length. Atlanta: U.S. Department of Health and Human Services; 2003. Available at: (http://www.atsdr.cdc.gov/HAC/asbestospanel/index.html).

5. Churg A. Asbestos-related disease in the workplace and the environment: controversial issues. In: Churg A, Katzenstein AA. The lung: current concepts (Monographs in pathology, no. 36). Philadelphia: Lippincott, Williams, and Wilkins; 1993. p. 54-77.

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

7. Berman DW, Crump KS. Technical support document for a protocol to assess asbestos-related risk (final draft). Prepared for USEPA Office of Solid Waste and Emergency Response. Washington DC: USEPA; October 2003.

8. U.S. Environmental Protection Agency. Guidelines for conducting the AHERA TEM clearance test to determine completion of an asbestos abatement project. Washington: U.S. Environmental Protection Agency, Office of Toxic Substances, NTIS No. PB90-171778. 1989.

9. US Environmental Protection Agency. Memorandum to P Peronard (On-Scene Coordinator, Libby Asbestos Site, USEPA Region 8) from CP Weiss (Senior Toxicologist/Science Support Coordinator, Libby Asbestos Site, USEPA Region 8) Amphibole mineral fibers in source materials in residential and commercial areas of Libby pose an imminent and substantial endangerment to public health. Denver: USEPA; December 20, 2001.

10. U.S. Environmental Protection Agency. Toxic air pollutants Web site. Accessed on October 29, 2002, at: http://www.epa.gov/air/toxicair/newtoxics.html.

11. Agency for Toxic Substances and Disease Registry. World Trade Center response activities. Close-out report. September 11, 2001–April 30, 2003. Atlanta: U.S. Dept. of Health and Human Services; May 16, 2003.

12. U.S. Environmental Protection Agency. World Trade Center indoor environment assessment: selecting contaminants of potential concern and setting health-based benchmarks. New York: USEPA Region 2; May 2003.

13. National Institute of Occupational Safety and Health (NIOSH). Online NIOSH pocket guide to chemical hazards. Accessed on July 16, 2002, at: http://www.cdc.gov/niosh/npg/npgd0000.html.

14. American Conference of Government Industrial Hygienists. 2000 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati; 2000.

15. U.S. Environmental Protection Agency. National primary drinking water regulations. Accessed on July 16, 2002, at: http://www.epa.gov/safewater/mcl.html.

Appendix C. Exposure pathways for vermiculite processing facilities*

Pathway	Environmental media and transport mechanisms	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.

Appendix D. Health Statistics Review for Populations in Close Proximity to the W.R. Grace & Company Facility in Glendale, California[6]

Background

In 1999 a series of articles in the *Seattle Post-Intelligencer* about high rates of asbestos-related disease brought national attention to the W.R. Grace & Company vermiculite mine in Libby, Montana. The Agency for Toxic Substances and Disease Registry (ATSDR), in cooperation with the Montana Department of Public Health and Human Services, analyzed mortality statistics (information on causes of death obtained from death certificates) for the Libby community for a 20-year period (1979–1998). This review found that death due to asbestosis was 40 times more common in the Libby population than in the rest of the state of Montana, and 80 times more common than in the rest of the U.S. population. Death due to lung cancer was 20% to 30% (1.2 to 1.3 times) higher than expected. Although rates of mesothelioma were elevated, it was not possible to quantify by how much. Still, these elevations were high enough that they were considered unlikely to have been due to natural fluctuations in the occurrence of these diseases [39]. Findings from the review of mortality statistics led to several follow-up activities to address the health impacts to those who lived and worked in Libby [40, 41].

Libby vermiculite was distributed to and processed by facilities located throughout the United States. Because human exposure to asbestos has possibly occurred in communities near these facilities, ATSDR's Division of Health Studies initiated a nationwide follow-up effort. This project is designed to screen for similar impacts on the health of populations living near facilities that received shipments of Libby vermiculite. As part of that effort, the Environmental Health Investigation Branch of the California Department of Health Services (CDHS) received funding to conduct health statistics reviews on communities located near facilities that processed or packaged Libby vermiculite.

Health statistics reviews are statistical analyses of information from **cancer registry** and **death certificate** records that investigate whether people in a particular community have developed cancer or have died from a particular disease more often than another comparison population. The health statistics reviews are being conducted in communities located near facilities that received Libby vermiculite, regardless of whether that community was in fact exposed to hazardous levels of asbestos from the vermiculite. (Usually, reviews of health information are conducted only when exposure to a harmful chemical is known to have occurred.) Communities are being investigated because, given the experience in the Libby community, it is not unrealistic to think that exposure to levels of asbestos high enough to have caused disease might have occurred in these communities.

> A **cancer registry** collects, organizes, and analyzes information on cancer cases that have been diagnosed or treated in a specific geographic area (for example, the State of California).
>
> A **death certificate** is an official, legal record of an individual's death. Death certificates provide information on the cause of death (as determined by a physician) and demographic information related to the person who died.

[6] Site assessment Section, Environmental Health Investigations Branch, California Department of Health Services.

Finding an excess of asbestos-related cancers or disease in a community would alert ATSDR and CDHS to the possibility that workers or community members might have been exposed to hazardous levels of asbestos as a result of the facility's handling or processing of Libby vermiculite. If, however, the health statistics review does not find an excess of asbestos-related disease, this does not prove that the community was not exposed to Libby asbestos.

This appendix presents the results of the health statistics review for the population living near the W.R. Grace & Company plant in Glendale, California.

Methods

CDHS followed a health statistics review protocol developed by ATSDR's Division of Health Studies (4). The objectives of this protocol are

1. to identify the residential area at highest risk of exposure to hazardous levels of asbestos from the exfoliation and processing of Libby vermiculite at the Glendale plant,
2. to determine whether the population living in this area had higher incidence rates of asbestos-related cancers than the U.S. population as a whole, and
3. to determine whether the population residing in this area had higher mortality rates from asbestos-related disease than the U.S. population as a whole.

The analysis of incidence rates of asbestos-related cancers will be referred to as the "cancer statistics review" and the analysis of mortality rates of asbestos-related disease will be referred to as the "mortality statistics review."

Incidence rate is a measure of the occurrence of disease in a population. It is the number of people in a population who get a disease in a specific time period, divided by the number of people in that population during the time period. For example, the incidence rate of lung cancer in California for the year 1997 was 60.1 new cases per 100,000 people living in California during that year (5).

Mortality rate is a measure of the occurrence of death from a disease in a population. It is the number of people in a population who die from a disease in a specific time period, divided by the number of people in that population during the time period. For example, the mortality rate for lung cancer in California for the year 1997 was 41.8 per 100,000 people residing in California during that year (6).

Diseases Evaluated in the Health Statistics Review

The ATSDR Division of Health Studies selected a variety of diseases for evaluation 1) to assess the full burden of disease and death that exposure to asbestos could have had on a population and 2) to confirm that the information obtained from cancer registries and vital statistics records for this review was consistent and therefore comparable.

Exposure to asbestos is known to cause lung cancer, mesothelioma, and asbestosis. Some studies suggest that exposure to asbestos might also increase the risk of certain digestive organ cancers. It is also possible that exposure to asbestos might worsen and cause premature death from certain diseases of the pulmonary and circulatory system.

One factor complicating the study of asbestos-related diseases is that physicians often misdiagnose these diseases, particularly when establishing a cause of death. This review also evaluated the number of people getting or dying from a certain disease because these people might have actually had an asbestos-related disease that was misdiagnosed.

Incidence rates of eight types of cancers or cancer groups were evaluated in the cancer statistics review (see list, at right). Lung and bronchus cancer, mesothelioma, and digestive organ cancers were studied because of their known or suspected association with asbestos exposure. Cancer of the peritoneum, retroperitoneum and pleura, and cancer of the respiratory system and intrathoriacic organs were evaluated because people with these diagnoses might actually have had an asbestos-related cancer instead. Lastly, all types of cancer, female breast cancer, and prostate cancer were evaluated to determine whether cancer was underreported to the cancer registries that provided information for this review.
Mortality rates from 13 types of diseases or disease groups were evaluated as part of the mortality statistics review (see list, at right). Lung and bronchus cancer, cancer of the peritoneum, retroperitoneum and pleura—including mesothelioma, asbestosis, and digestive organ cancers were evaluated because of their known or suspected association with asbestos exposure. Respiratory system and intrathoriacic organ cancers, cancer with no specification of site, pneumoconioses, and chronic obstructive pulmonary disease were evaluated because these deaths might actually have resulted from misdiagnosed asbestos-related diseases. Chronic obstructive pulmonary disease, disease of the pulmonary circulation, and other diseases of the respiratory system were evaluated because asbestos-exposure might have worsened these conditions and led

The cancer statistics review evaluated the following types of cancer:

Lung and bronchus

Mesothelioma

Digestive organs

Peritoneum, retroperitoneum, and pleura

Respiratory system and intrathoracic organs

All types of cancer

Female breast

Prostate

The mortality statistics review evaluated death from the following diseases:

Lung and bronchus cancer

Cancer of the peritoneum, retroperitoneum and pleura—including mesothelioma

Asbestosis

Digestive organ cancers

Respiratory system and intrathoracic organ cancers

Cancer—no specification of site

Pneumoconioses

Chronic obstructive pulmonary disease

Diseases of pulmonary circulation

Other diseases of respiratory system

All types of cancer

Female breast cancer

Prostate cancer

to premature death. Finally, all types of cancer, female breast cancer, and prostate cancer were evaluated to determine whether causes of death were underreported to the registries that provided information for the mortality statistics review.

Studying mesothelioma

During the years that were evaluated in this review, cancer and causes of death were coded in cancer registries and on death certificates according to two classification systems: the International Classification of Diseases—Oncology Codes, Revision 2 (ICD-O-2) (used by cancer registries), and the International Classification of Diseases, Injury, and Causes of Death Codes, Revision 9 (ICD-9) (used for death certificates).

The ICD-O-2 system has a specific code for mesothelioma, which makes it possible to evaluate the incidence rate of this cancer in the Glendale community. In contrast, the ICD-9 system does not have a specific code for mesothelioma. Therefore, it is not possible to analyze mortality rates for mesothelioma alone; only a larger group of diseases (cancer of the peritoneum, retroperitoneum, and pleura—including mesothelioma) can be studied. Nearly all of the deaths in this cancer group are, in fact, deaths from mesothelioma (W. Kaye, ATSDR, personal communication, 2004). So, evaluating mortality from this group of cancers reflects, with relative accuracy, the occurrence of death from mesothelioma.

Study Populations

As discussed earlier in this health consultation, whether people who lived near the Glendale plant between 1950 and 1977 were exposed to hazardous levels of asbestos from Libby vermiculite, and if so, which areas of Glendale experienced such exposure, is currently unknown [42]. Therefore, the first step of the health statistics review was to determine which area near the Glendale plant was most likely to have experienced an increased burden of asbestos-related disease (assuming that the Glendale plant did pollute the surrounding air with hazardous levels of asbestos). CDHS concluded that the population living within ½-mile of the Glendale plant site was the most likely population to have been exposed to levels of asbestos high enough to cause a detectable excess burden of asbestos-related disease. This distance was selected on the basis of information presented in this health consultation and information from health studies of lung cancer and mesothelioma rates in communities near asbestos industries .

Figure E–1 shows the location of the Glendale plant and the area of Glendale that is located within ½-mile of the facility. The health statistics review would ideally evaluate the incidence and mortality rates of asbestos-related disease in the population residing in this area. But the smallest geographic area on which cancer statistics are publicly available is the **census tract** (providing information on a smaller geographic area could make it possible to identify a cancer patient, and thus would violate their right to privacy). For similar reasons pertaining to privacy, the smallest geographic area on which mortality statistics are publicly available is the ZIP code.

> **Census tracts** are small geographic areas defined by the U.S. Census Bureau. Census tracts usually have 2,500 to 8,000 residents with similar population characteristics, economic status, and living conditions.

Therefore, for the cancer statistics review, CDHS studied the population living in census tracts 1881, 3017, and 3023. For the mortality statistics review, CDHS studied the population residing in ZIP codes 90039, 91203, and 91204. Figure E–2 shows the location of the Glendale plant, the area that CDHS determined was most likely to experience an excess of asbestos-related disease, and census tracts 1881, 3017, and 3023. Figure E–3 shows the location of the Glendale plant, the area that CDHS determined was most likely to experience an excess of asbestos-related disease, and ZIP codes 90039, 91203, and 91204.

Figure E–1. Area of Glendale that is most likely to have been exposed to levels of asbestos high enough to cause a detectable excess burden of asbestos-related disease, assuming that the Glendale plant polluted the outside air with hazardous levels of asbestos.

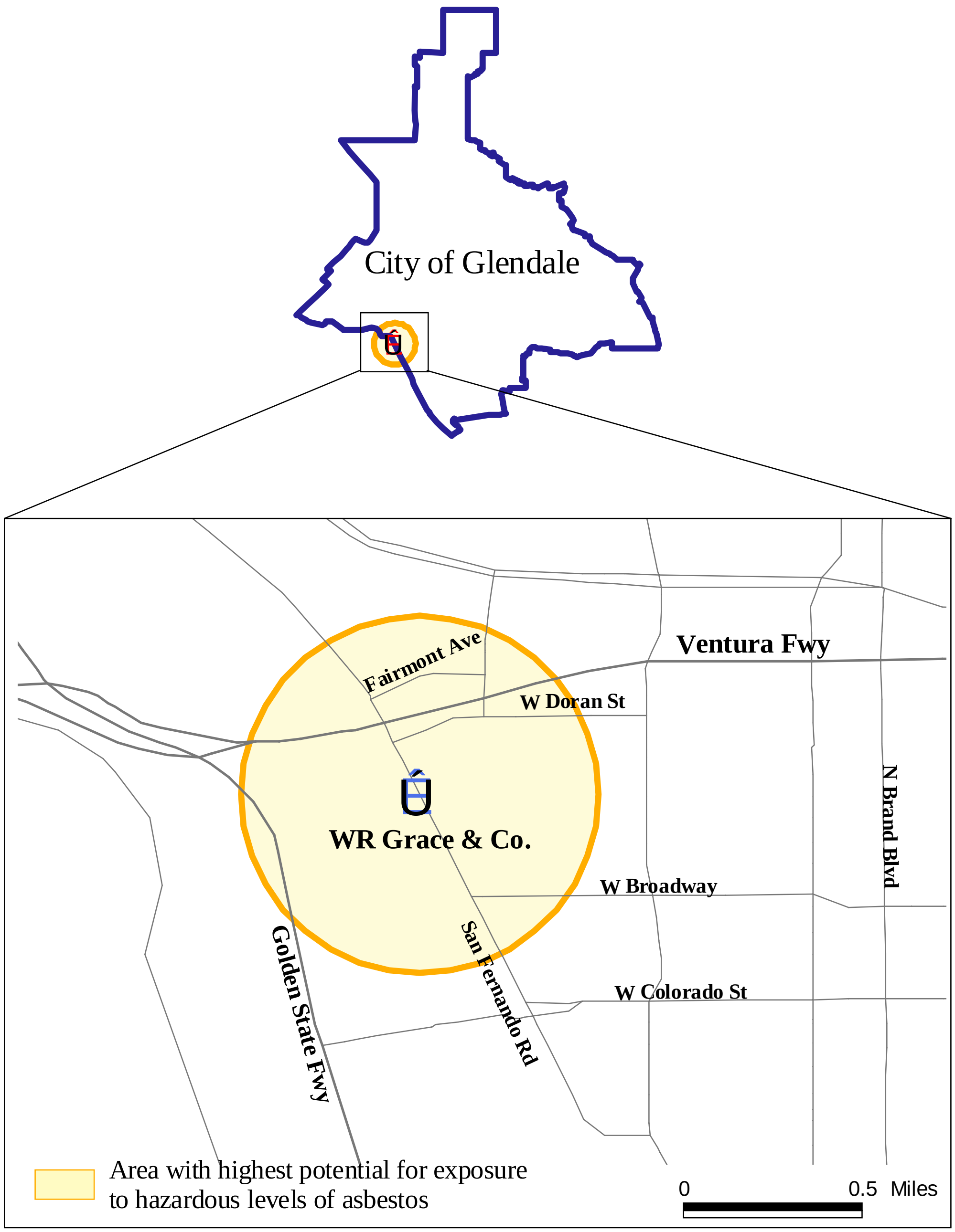


Figure E–2. Map of census tracts 1881, 3017, and 3023 in relationship to the area located within ½ mile of the Glendale plant, Glendale, California.

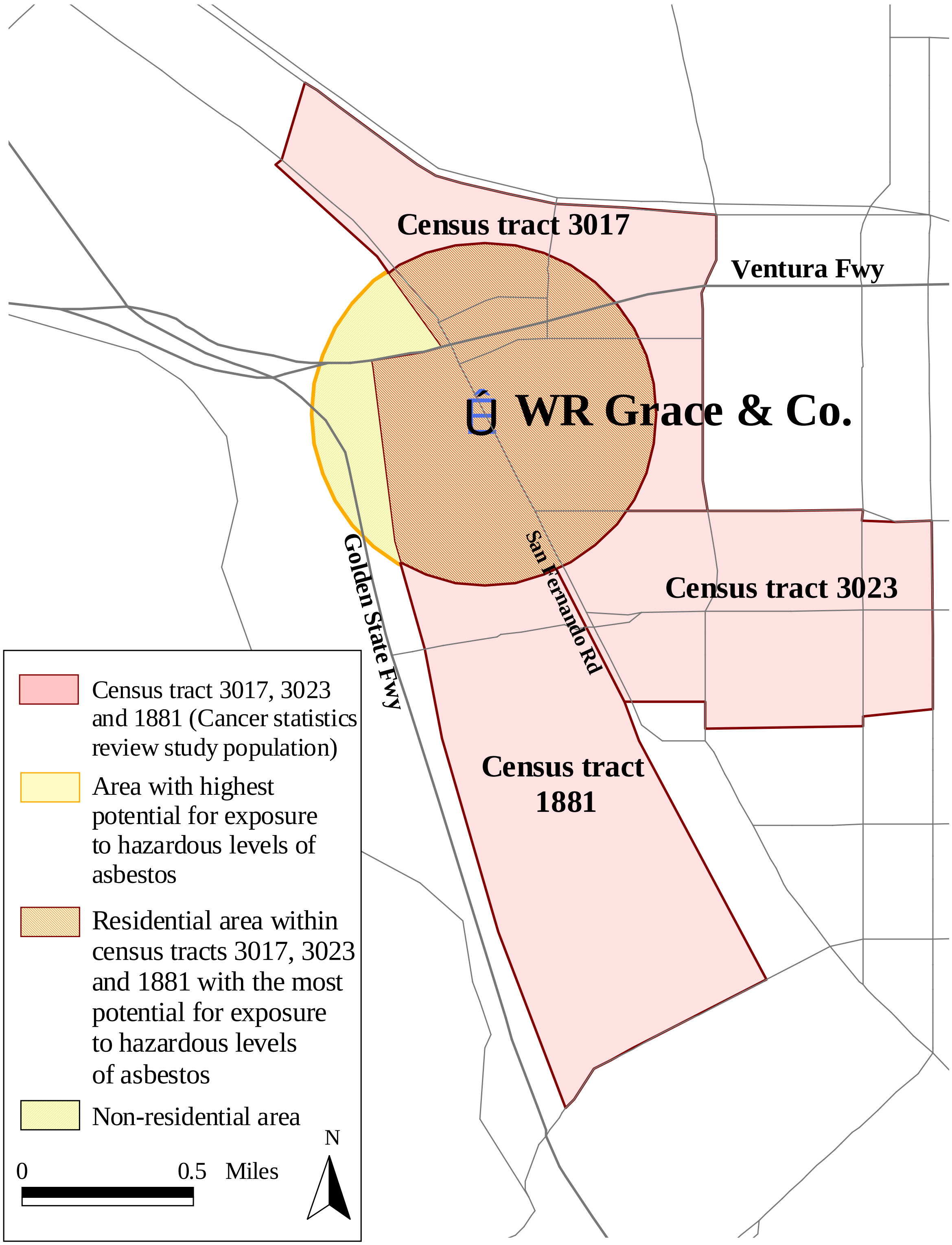
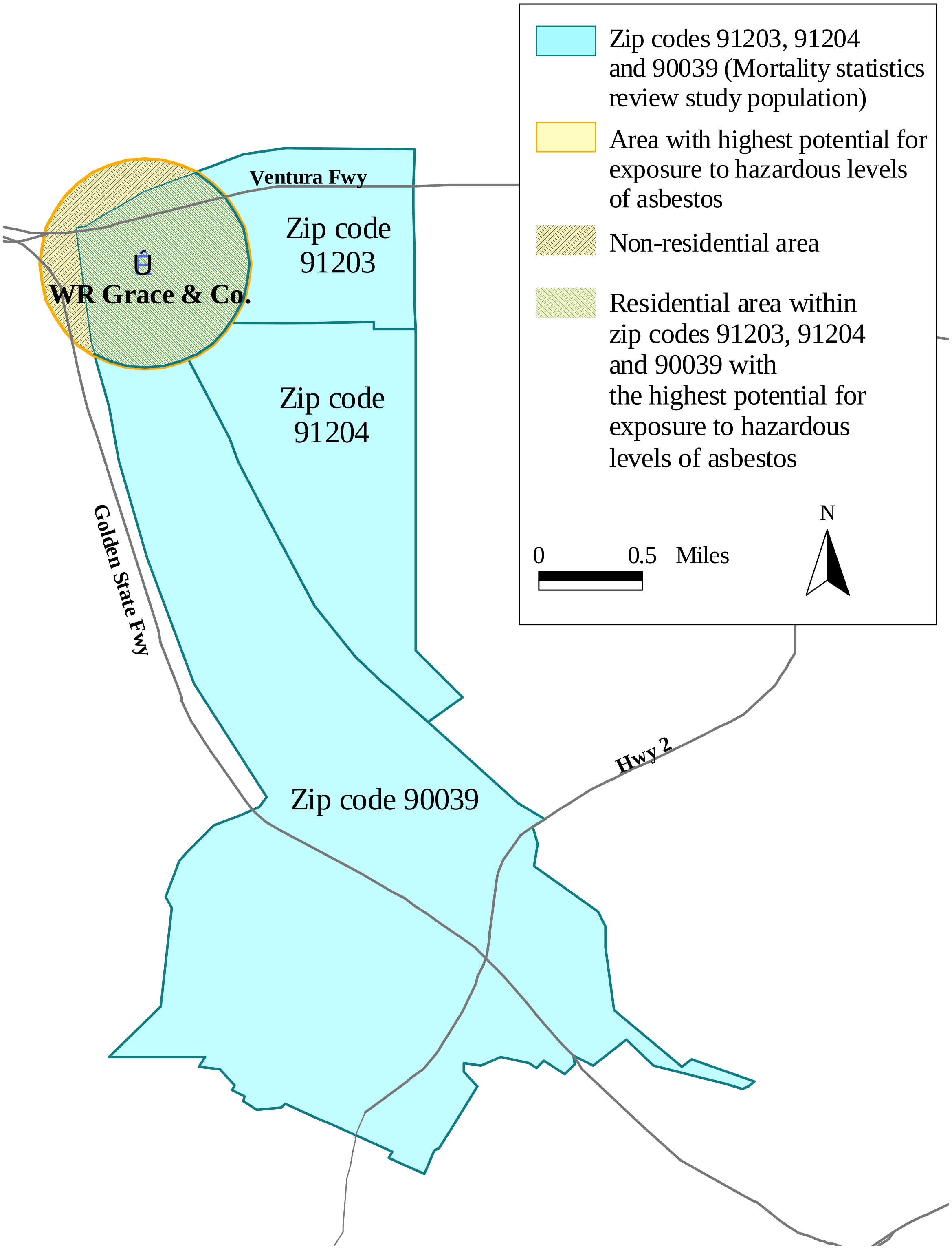


Figure E–3: Map of ZIP codes 90039, 91203, and 91204 in relationship to the area located within ½ mile of the Glendale plant, Glendale, California.



Study Periods

The cancer statistics review studied the period from January 1, 1986, through December 31, 1995, and the mortality statistics review studied the period January 1, 1989, through December 31, 1998. ATSDR selected these periods for two reasons: 1) they come closest to corresponding to the time of exposure and the latency period of asbestos-related disease; and 2) a 10-year period provides the minimum amount of data required for informative statistical analysis [43].

Demographic Information on the Study Populations

In 1990, there were 21,945 people residing in census tracts 1881, 3017, and 3023, and 57,615 people residing in ZIP codes 90039, 91203, and 91204 (see Table E–1). Both study populations had more males, fewer whites, and larger Asian/Pacific Islander and Hispanic (white and other race) than the U.S. population. The study populations were similar to the U.S. population with respect to age, education and employment status. However, the study populations did have higher rates of poverty than the U.S. population.

Statistical Analysis

The statistical analysis was designed to screen for an excess of asbestos-related disease in communities with facilities that received Libby vermiculite. Specifically, the analysis explored the following questions:

1. Is the number of people who were diagnosed with an asbestos-related cancer while residing in census tracts 1881, 3017, and 3023 from 1986–1995 higher than what we would expect if the incidence rates of these cancers in the cancer study population were the same as the rates in the U.S. population as a whole?

Table E–1. Demographic Characteristics of the Populations Living in Census Tracts 1881, 3017, and 3023, in ZIP Codes 90039, 91203, and 91204, and in the United States

	Census Tracts 1881, 3017, 3023	**ZIP Code 90039, 91203, and 91204**	**U.S.**
Total population	21,945	57,615	
Sex			
Males	51%	51%	49%
Females	49%	49%	51%
Race/Ethnicity			
non-Hispanic			
White	45%	41%	76%
Black	2%	2%	12%
Asian/Pacific Islander	14%	17%	3%
Other Race	0%	0%	0%
Hispanic			
White	16%	16%	5%
Other race	22%	22%	4%
Age			
under 18 years old	24%	22%	26%
18-64 years old	65%	67%	62%
65 and over	11%	11%	12%
Education			
less than 9th grade	18%	17%	9%
some high school	16%	15%	15%
high school graduate	21%	20%	30%
some college or higher	46%	49%	45%
Employment			
in labor force	64%	67%	65%
not in labor force	36%	33%	35%
employed	91%	93%	94%
unemployed	9%	7%	6%
Poverty			
Income below poverty level	19%	16%	13%

2. Are the incidence rates of asbestos-related cancers in census tracts 1881, 3017, and 3023 population from 1986–1995 higher than the rates in the U.S. population as a whole?

3. Is the number of people who died from asbestos-related disease while residing in ZIP codes 90039, 91203, and 91204 from 1989–1998 higher than what we would expect if mortality rates in the mortality study population were the same as the mortality rates in the U.S. population?

4. Are the mortality rates for asbestos-related disease in the ZIP codes 90039, 91203, and 91204 population from 1989–1998 higher than the mortality rates for the U.S. population as a whole from 1989–1998?

These four questions are similar in that they all compare the incidence and mortality rates in the Glendale community with the incidence and mortality rates in the U.S. population as a whole. They differ, however, in how the comparison is made.

Statistical Measures of Comparison

The first question is explored by calculating a statistical measure called the **standardized incidence ratio (SIR)**. The SIR is a numerical expression. In this review the SIR mpares how many people in the census tracts 1881, 3017, and 3023 population were diagnosed with cancer and how many diagnoses would be expected (hypothetically) if the incidence rate of cancer in the census tracts 1881, 3017, and 3023 population was the same as the incidence rate of cancer in the U.S. population. Details on how the SIR is calculated are provided in Addendum 1. If the number of people who were diagnosed with an asbestos-related cancer while residing in census tracts 1881, 3017, and 3023 is the same as the expected number, the SIR will equal 1. If the number of people in the census tracts 1881, 3017, and 3023 population who were diagnosed with an asbestos-related cancer is less than the expected number, the SIR will be less than 1. If the number of people in the census tracts 1881, 3017, and 3023 population who were diagnosed with an asbestos-related cancer is more than one would expect, the SIR will be greater than 1.

The second question is explored by calculating a statistical measure called the **standardized rate ratio (SRR)**. The SRR is a numerical expression, and in this review the SRR compares how many people in the United States were diagnosed with cancer and how many would be expected (hypothetically) if the U.S. population had the same incidence rates of cancer as the census tracts 1881, 3017, and 3023 population. Details on how the SRR is calculated are provided in Addendum 2. If the incidence rate of cancer in the U.S. population is the same as that in the census tracts 1881, 3017, and 3023 population, the SRR will equal 1. If the incidence rate of cancer in the U.S. population is lower than the incidence rate in the census tracts 1881, 3017, and 3023 population, then the SRR will be less than 1. And, if the incidence rate of cancer in the U.S. population is higher than that in the census tracts 1881, 3017, and 3023 population, the SRR will be greater than 1.

The third question is explored by calculating a statistical measure called the **standardized mortality ratio (SMR)**. The SMR is essentially the same measure as the SIR except that it evaluates the number of people who died from a disease rather than the number of people who were diagnosed with a disease. Thus the SMR is a numerical expression that compares how many people in ZIP codes 90039, 91203, and 91204 died of an asbestos-related disease and how many would be expected to die (hypothetically) if the mortality rates of asbestos-related disease in the ZIP codes 90039, 91203, and 91204 populations were the same as the mortality rates in the U.S. population. Details on how the SMR is calculated are provided in Addendum 3. If the number of people who died from an asbestos-related disease while residing in ZIP codes 90039, 91203, and 91204 is the same as the expected number, the SMR will equal 1. If the number of ZIP codes 90039, 91203, and 91204 residents who died from an asbestos-related disease is less than the expected number, the SMR will be less than 1. If the number of persons in ZIP codes 90039, 91203, and 91204 who died from an asbestos-related disease is more than would be expected, the SMR will be greater than 1.

Lastly, the fourth question is also answered by calculating a standardized rate ratio (SRR), but for mortality rates instead of cancer incidence rates. So the SRR in this case is a numerical expression that compares the number of people in the United States who died from an asbestos-related disease and the number of people in the United States who would be expected (hypothetically) to die, if the U.S. population had the same mortality rate as the ZIP codes 90039, 91203, and 91204 populations.

Interpreting the expected number of people to get a disease or die from a disease

The SIR, SMR, and SRR all compare the actual number of persons who get a disease or die from a disease with an expected number. This expected number of persons is a calculated and theoretical number that is often not a whole number. For example, the expected number might be 2.6 persons. Because it is not possible for a fraction of a person to get or die from a disease, the expected number can be thought of as an approximation. In this example, the expected number (2.6 persons) can be interpreted to mean that either 2 or 3 people are expected to get a disease or die from a disease.

Accounting for differences between the study populations and the comparison population

In this review, the incidence and mortality rates of disease in the Glendale and U.S. populations are compared because it is thought that the Glendale population might have higher rates of disease due to past exposure to harmful levels of asbestos. But other characteristics can also increase the risk for developing many of the diseases linked to asbestos. If the study populations differ from the U.S. population in terms of how common these characteristics are, then these differences can bias (i.e., create a faulty appearance in) the results of the comparison unless they are accounted for in the analysis. For example, smoking can increase the risk of developing lung cancer. If smoking rates in the Glendale populations are lower than the smoking rates in the U.S. population, but the analysis does not adjust for this difference, then the study populations might appear to have lower rates of lung cancer in comparison with the U.S. population than they in fact do. This bias can hide a true excess of disease or it can create the appearance of an excess when none really exists.

This analysis did account for differences in age and sex, but did not account for other risk factors for asbestos-related disease (for example, smoking, race/ethnicity, or socioeconomic status).

Statistical Tests

The number of people who get or die from cancer or other diseases in a given geographic area changes from year to year; this fluctuating pattern is characteristic of the occurrence of disease and is expected. Because of this, the values of the SIR, the SMR, and the SRR will also change, depending on which time period is under study. If the number of cases occurring in one time period under study is higher than average, then the SIR, SMR, or SRR will be higher than 1 (for example, 1.2). If a different time period were under study and the number of cases were lower than average, the SIR, SMR, and SRR would be less than 1 (for example, 0.9). Some degree of fluctuation in the SIR, SMR, and SRR values from one time period to another is normal and expected.

An important question is when is an SIR, an SMR, or an SRR higher or lower than what would be expected, given that the number of people getting disease in a given geographic area normally varies over time? In other words, is the incidence rate or mortality rate in the Glendale population the same as that in the U.S. population, or is disease or death occurring less or more frequently in the Glendale population than in the U.S. population as a whole?

To answer this question, a statistical test measure called a **confidence interval (CI)** was calculated for the SIR, the SMR, and the SRR using Byar's approximation method . A confidence interval is a range of possible values for the SIR, SMR, or SRR that are consistent with the normal variation in disease over time in a geographic area. If the CI range includes the value 1, then there is no "statistically significant" difference between the incidence or mortality rates in the Glendale and U.S. populations, as represented by the SIR, SMR or SRR. In other words, the incidence or mortality rate in the Glendale population is the same as the incidence or mortality rate in the U.S. population. If the CI range is less than one or greater than 1, then there is a "statistically significant" difference between the incidence or mortality rates in the two populations, and the incidence rate or mortality rate in the Glendale population is not the same as the incidence rate or mortality rate in the U.S. population.

Part of the process of calculating a confidence interval includes selecting a level of certainty for this statistical test. CDHS used a 95% level of certainty, which is the standard value selected for these types of analyses.

Sources of Information on Incidence and Mortality Rates

Information on the number of people who developed cancer while residing in census tracts 1881, 3017, and 3023 was obtained from the California Cancer Registry (CCR). Information on cancer rates in the U.S. population was obtained from the Surveillance, Epidemiology, and End Results program of the National Cancer Institute (SEER) .

Information on the number of people who died while residing in ZIP codes 90039, 91203, and 91204 was obtained from CDHS, Center for Health Statistics, Office of Vital Records (CDHS-OVR). Information on mortality rates in the U.S. population was obtained from the National Center for Health Statistics (NCHS) .

Results of the Cancer Statistics Review

The standardized incidence ratios and standardized rate ratios for the census tracts 1881, 3017, and 3023 population are presented in Table E–2.

For each cancer group studied, Table E–2 shows the reason for studying that type of cancer.

For the SIR analysis, Table E–2 shows

- the number of persons who were diagnosed with the type of cancer while residing in census tracts 1881, 3017, and 3023;
- the number of persons expected to be diagnosed (if the census tracts 1881, 3017, and 3023 population had the same incidence rate as the U.S. population); and
- the SIR and 95% CI for the SIR.

For the SRR analysis, Table E–2 shows

- the number of persons who were diagnosed with the type of cancer while residing in the United States;
- the number of persons expected to be diagnosed (if the U.S. population had the same incidence rate as the census tracts 1881, 3017, and 3023 population); and
- the SRR and the 95% CI for the SRR.

Table E–2. Standardized Incidence Ratio (SIR), Standardized Rate Ratio (SRR), and 95% Confidence Intervals (CI) of Selected Cancers in the Census Tracts 1881, 3017, and 3023 Population, 1986–1995

Cancer Group (ICD-O-2 Code)	Reason†	Census Tracts 1881, 3017, and 3023		SIR (95% CI)	United States		SRR (95% CI)
		# of diagnoses	expected#		# of diagnoses	expected #	
Lung and bronchus (C340:C349*)	1	100	117.4	0.85 (0.69–1.04)	148,246	132,350.9	0.89 (0.74–1.08)
Mesothelioma (M-9050:9053)	1	1	1.9	0.53 (0.01–2.96)	2,360	1,724.6	0.73 (0.14–3.82)
Digestive organs (C150: C218, C260:C269*)	2	101	139.5	0.72 (0.59–0.88)	163,384	123,625.5	0.76 (0.62–0.92)
Respiratory system and intrathoracic organs (C320:C399*)	3	111	128.2	0.87 (0.71–1.04)	162,067	147,728.0	0.91 (0.76–1.09)
Peritoneum, retroperitoneum, and pleura (C480:C488, C384*)	3	1	3.1	0.32 (0.00–1.78)	3,814	1,724.6	0.45 (0.09–2.36)
All cancers (C000:C809*)	4	582	870.6	0.67 (0.62–0.73)	1,045,968	715,781.5	0.68 (0.63–0.74)
Female breast (C500:C509*)	4	104	130.6	0.80 (0.65–0.97)	154,568	126,577.8	0.82 (0.67–0.99)
Prostate (C619*)	4	79	118.1	0.67 (0.53–0.83)	153,845	101,505.9	0.66 (0.53–0.83)

*excluding M-9590:9989

†Reason for studying:

1. Exposure to asbestos is known to cause a type of cancer in this cancer group.
2. There is some, but inconclusive, evidence that exposure to asbestos might be associated with some digestive organ cancers.
3. This cancer group might include people with an asbestos-related cancer that was misdiagnosed.
4. This cancer or cancer group was studied to confirm that information on cancer diagnoses is reported to CCR and SEER in a consistent manner.

Between 1986 and 1995, the incidence rates of asbestos-related cancers in the census tracts 1881, 3017, and 3023 population were not statistically significantly different from the incidence rates in the U.S. population. One hundred people were diagnosed with lung or bronchial cancer, when 117.4 diagnoses would be expected if the incidence rate in the census tracts 1881, 3017, and 3023 population was the same as the incidence rate in the U.S. population (SIR=0.85). The 95% CI (0.69–1.04) indicates that there is no statistically significant difference between the incidence rates of lung and bronchus cancer in the census tracts 1881, 3017, and 3023 population and the U.S. populations, as measured by the SIR. Similarly, the SRR for lung and bronchus cancer was 0.89, with a 95% CI of (0.74–1.08). There is also no statistically significant difference between the incidence rates of lung and bronchus cancer in the census tracts 1881, 3017, and 3023 population and U.S. populations, as measured by the SRR. One person was diagnosed with mesothelioma, when 1.9 diagnoses would be expected if the census tracts 1881, 3017, and 3023 population had the same incidence rate as the U.S. population (SIR=0.53), and the SRR for this cancer was 0.73. However, the 95% CIs for the SIR (0.01–2.96) and the SRR (0.14–3.82) indicate that there is no statistically significant difference between the incidence rate of mesothelioma in the census tracts 1881, 3017, and 3023 population and that in the U.S. population during the years 1986–1995.

Between 1986 and 1995 the incidence rate of digestive organ cancers in the census tracts 1881, 3017, and 3023 population was statistically significantly lower than the incidence rate in the U.S. population, as measured by the SIR analysis (SIR=0.72; 95% CI, 0.59–0.88) and the SRR analysis (SRR=0.76; 95% CI, 0.62–0.92).

The incidence rate of cancer of the respiratory system and intrathoracic organs in the census tracts 1881, 3017, and 3023 population was not statistically significantly different from the incidence rate in the U.S. population, as evaluated by the SIR analysis (SIR=0.87; 95% CI, 0.71–1.04) and the SRR analysis (SRR=0.91; 95% CI, 0.76–1.09). Neither was the incidence rate of cancer of the peritoneum, retroperitoneum, and pleura in the census tracts 1881, 3017, and 3023 population statistically significantly different from that in the U.S. population (SIR=0.32; 95% CI 0.00–1.78) and (SRR=0.45; 95% CI, 0.09–2.36).

Finally, according to both the SIR and SRR analysis, the incidence rates of all types of cancer, female breast cancer and prostate cancer in the census tracts 1881, 3017, and 3023 population were all statistically significantly lower than the incidence rates in the U.S. population. For all types of cancer, the SIR=0.67 and 95% CI, 0.62–0.73; and the SRR=0.68 and 95% CI, 0.63–0.74. For female breast cancer, the SIR=0.80 and 95% CI, 0.65–0.97; and the SRR=0.82 and 95% CI, 0.67–0.99. For prostate cancer, the SIR=0.67 and 95% CI, 0.53–0.83; and the SRR=0.66 and 95% CI, 0.53–0.83.

Results of the Mortality Statistics Review

Standardized mortality ratios and standardized rate ratios for the ZIP codes 90039, 91203, and 91204 population are presented in Table E–3.

For each disease group studied, Table E–3 shows the reason for studying the disease.

For the SMR analysis, Table E–3 shows

- the number of persons who died from the disease while residing in ZIP codes 90039, 91203, and 91204;
- the number of persons expected to die (if this population had the same disease mortality rate as the U.S. population); and
- the SMR and 95% CI for the SMR.

For the SRR analysis, Table E–3 shows

- the number of persons who died from the disease while residing in the Unites States;
- the number of persons expected to die (if the U.S. population had the same disease mortality rate as the ZIP codes 90039, 91203, and 91204 population); and
- the SRR and 95% CI for the SRR.

Table E–3. Standardized Mortality Ratio (SMR), Standardized Rate Ratio (SRR), and 95% Confidence Intervals (CI) of Selected Causes of Death Occurring in ZIP Codes 90039, 91203, and 91204, 1989–1998

Cause of Death (ICD-9 Code)	Reason*	ZIP Codes 90039, 91203, and 91204		SMR (95% CI)	U.S. population		SRR (95% CI)
		# deaths	expected #		# deaths	expected #	
Cancer of the lung and bronchus (162.2–162.9)	1	210	285.0	**0.74 (0.64–0.84)**	1,476,326	1,099,657.7	**0.74 (0.70–0.80)**
Cancer of the peritoneum, retroperitoneum and pleura (including mesothelioma) (158, 163)	1	0	2.1	0†	10,615	0.0	0‡
Asbestosis (501)	1	0	0.6	0†	3,367	0.0	0‡
Cancer of the digestive organs (150–154, 159)	2	155	170.1	0.91 (0.77–1.07)	832,523	793,750.5	0.95 (0.88–1.03)
Cancer of the respiratory system and intrathoracic organs (161–165)	3	217	294.4	**0.74 (0.64–0.84)**	1,524,872	1,136,320.2	**0.75 (0.70–0.80)**
Cancer - no site specified (199)	3	56	66.6	0.84 (0.64–1.09)	327,646	279,886.6	**0.85 (0.75–0.97)**
Pneumoconiosis (500–505)	3	0	2.2	0 (0–1.68)†	11,617	0.0	0‡
Chronic obstructive pulmonary disease (490–496)	3, 4	203	199.5	1.02 (0.88–1.17)	986,772	1,026,099.6	1.04 (0.97–1.11)
Other diseases of the respiratory system (510–519)	4	27	36.2	0.75 (0.49–1.09)	172,155	131,759.8	**0.77 (0.64–0.92)**
Diseases of pulmonary circulation (415–417)	4	12	25.2	**0.48 (0.25–0.83)**	119,554	58,052.7	**0.49 (0.37–0.64)**
All cancers (140–208)	5	782	1055.0	**0.74 (0.69–0.80)**	5,259,810	3,990,298.0	**0.76 (0.73–0.79)**
Female breast cancer (174)	5	109	89.5	1.22 (1.00–1.47)	430,680	536,738.3	**1.25 (1.13–1.37)**
Prostate cancer (185)	5	47	64.5	**0.73 (0.54–0.97)**	334,151	255,394.9	**0.76 (0.66–0.88)**

* Reason for studying:

1. Exposure to asbestos is known to cause a type of cancer in this cancer group or this disease.
2. There is some, but inconclusive, evidence that exposure to asbestos might be associated with some digestive organ cancers.
3. This cancer group might include people with an asbestos-related cancer that was misdiagnosed.
4. Exposure to asbestos might have exacerbated the condition of people with these diseases and thereby led to premature or increased chance of death.
5. This cancer or cancer group was studied to confirm that information is reported to the CDHS-OVR and the NCHS in a consistent manner.

† Exact confidence interval based on Poisson distribution.

‡ Confidence interval not calculated since expected number of deaths was 0 (W. Kaye, ATSDR, personal communication, 2004).

Bold typeface indicates a statistically significant result.

The mortality statistics review found no evidence that the ZIP codes 90039, 91203, and 91204 population experienced statistically significantly higher rates of death from some asbestos-related disease than the U.S. population between the years 1989–1998. In fact, the mortality study population had statistically significantly lower mortality rates for cancer of the lung and bronchus: SMR=0.74 and 95% CI 0.64–0.84; and SRR=0.74 and 95% CI 0.70–0.80. And there was no statistically significant difference between the mortality rates for cancer of the peritoneum, retroperitoneum, and pleura (including mesothelioma) and for asbestosis in the 90039, 91203, 91204 and U.S. populations. For cancer of the peritoneum, retroperitoneum and pleura–including mesothelioma, the SMR=0 and the SRR=0. For asbestosis, the SMR=0 and the SRR=0.

The mortality statistics review found no evidence that the ZIP codes 90039, 91203, and 91204 population and U.S. population had different mortality rates for digestive organ cancers. The SMR=0.91 and 95% CI 0.77–1.07, and the SRR=0.95 and 95% CI 0.88–1.03.

The rate of death from cancer of the respiratory system and intrathoracic organs was statistically significantly lower in the ZIP codes 90039, 91203, and 91204 population than in the U.S. population. The SMR=0.74 and 95% CI 0.64–0.84; and the SRR=0.75 and 95% CI 0.70–0.80. The mortality statistics review found inconsistent evidence that the ZIP codes 90039, 91203, and 91204 population experienced statistically significantly lower rates of death from cancer with no site specified: the SMR analysis found no statistically significant difference between the rates in the two populations (SMR=0.84 and 95% CI 0.64–1.09), but the SRR analysis found a lower risk in the ZIP codes 90030, 91203, and 91204 (SRR=0.85 and 95% CI 0.75–0.97). Neither the SMR nor the SRR analyses found evidence that the ZIP codes 90039, 91203, and 91204 population and U.S. population had different rates of death from pneumoconiosis (SMR=0 and 95% CI 0–1.68, and SRR=0) or from chronic obstructive pulmonary disease (SMR=1.02 and 95% CI 0.88–1.17; and SRR=1.04 and 95% CI 0.97–1.11).

The SMR analysis did not find evidence that the rate of death from other diseases of the respiratory system was different in the ZIP codes 90039, 91203, and 91204 population and the U.S. population (SMR=0.74 and 95% CI 0.49–1.09). However, the SRR analysis did find evidence that the ZIP codes 90039, 91203, and 91204 population had statistically significantly lower rates of death from this disease (SRR=0.77 and 95% CI 0.64–0.92). Both the SMR and the SRR analyses indicated that the ZIP codes 90039, 91203, and 91204 population had statistically significantly lower rates of death from diseases of the pulmonary circulation: SMR=0.48 and 95% CI 0.25–0.83; and SRR=0.49 and 95% CI 0.37–0.64.

Finally, this analysis indicated that the rates of death from all cancers and from prostate cancer were statistically significantly lower in the ZIP codes 90039, 91203, and 91204 population than in the U.S. population. For all cancers, the SMR=0.74 and 95% CI 0.69–0.80, and the SRR=0.76 and 95% CI 0.73–0.79. For prostate cancer, the SMR=0.73 and 95% CI 0.54–0.97, and the SRR=0.76 and 95% CI 0.66–0.88. Evidence that the ZIP codes 90039, 91203, and 91204 population and the U.S. population had statistically significantly different rates of death from female breast cancer was inconsistent. According to the SMR analysis (SMR=1.22 and 95% CI 1.00–1.47), the ZIP codes 90039, 91203, and 91204 population and U.S. population had the same mortality rate, but according to the SRR analysis (SRR=1.25 and 95% CI 1.13–1.37), the

ZIP codes 90039, 91203, and 91204 population had higher rates of death from female breast cancer than the U.S. population.

Discussion

Five limitations of this analysis are worth discussion and exploration because they might 1) affect the accuracy of the results, 2) limit the ability of the analyses to observe an excess of asbestos-related disease attributable to vermiculite processing at the Glendale plant, if one exists, or 3) limit the degree to which this analysis can serve as an indicator of community exposure to Libby asbestos.

1. **The SIR, SMR, and SRR results might be biased if the analyses do not account for the ways that the Glendale and U.S. population differ with respect to other risk factors for asbestos-related diseases (such as race/ethnicity, socioeconomic status, and smoking).**

As discussed previously, this analysis does not account for all the ways that the Glendale population differs from the U.S. population with respect to risk factors for diseases that can be caused by exposure to asbestos. As a result, this analysis might not accurately identify an excess or lack of excess of disease attributable to asbestos exposure.

To assess whether the Glendale and U.S. populations differ with respect to other risk factors for asbestos-related disease, CDHS gathered information from the U.S. Census. Table E–1 shows that the population in census tract 1881, 3017, and 3023 differs substantially from the U.S. population in terms of race/ethnicity and socioeconomic status (measured by education level and poverty status). So, too, do the ZIP codes 90039, 91203, and 91204 population differ substantially from the U.S. population in terms of these characteristics. No information on smoking rates in the study populations is available. That said, however, smoking has historically been less common in California , and, since the late 1980s, smoking rates in California have been declining more rapidly than the rest of the country [44]. Smoking rates also tend to be higher among people of low socioeconomic status [45] and tend to differ by race and ethnicity . Using these statewide trends, it is likely that the smoking rates in the Glendale study populations are different from those in the U.S. population.

It is not possible to predict whether or how the combined racial, ethnic, and socioeconomic differences between the study and U.S. populations could bias the analysis (in other words, whether they could be masking a true elevation in rates of asbestos-related disease.) However, any conclusions drawn this health statistics review could be made more definitively if these differences were accounted for in the SIR, SMR, and SRR analyses.

2. **The results of the analyses might be inaccurate if the study populations are larger or smaller than they are assumed to be.**

Information on the size of the study populations during the study periods (1986–1995 for the cancer statistics review and 1989–1998 for the mortality statistics review) is needed to calculate the SIR, SMR, and SRRs as well as the 95% CIs. Information on the size of the populations in census tracts and ZIP codes is collected by the U.S. Census once every decade, but not during the intervening years. Therefore, to calculate the statistical measures of comparison, ATSDR made the customary assumption that the size of the study populations in 1990 (as determined by the U.S. Census) represents the average size of the populations during the study periods.

If this assumption does not hold true, then the results of the SIR, SMR, and SRR analyses will be biased (inaccurate). Specifically, if the size of the study populations in 1990 is smaller than the average size of the study populations during the study periods, then the SIR, SMR, and SRR will be inaccurately high numbers, and the statistical tests might falsely indicate a statistically significant excess of disease. And, conversely, if the size of the study populations in 1990 is larger than the average size of the study populations during the study periods, then the SIR, SMR, and SRR will be inaccurately low numbers, and the statistical tests might falsely indicate a lack of disease excess.

Without knowing the true size of the study populations during the study periods, it is not possible to predict whether these statistical measures might be biased or how they might be biased. Still, it is possible to obtain some sense of whether any bias is occurring by referring to information on the size of these populations during U.S. Census years (e.g., 1980, 1990). According to U.S. Census data, the census tracts 1881, 3017, and 3023 population grew by 36% between 1980 and 1990 and by 4% between 1990 and 2000 [46]. If these trends represent the growth of the census tract population between 1986 and 1995, then the assumed size of the cancer statistics review study population is smaller than the true size. This difference will bias the values of the SIR, SRR, and 95% CIs in a way that makes them higher than they actually are.

The ZIP codes 90039, 91203, and 91204 population grew by 5% between the years 1990 and 2000 [46]. If this trend represents the growth of this population during the years 1989 and 1998, then the assumed size of the mortality statistics review study population is smaller than the true size. This difference will bias the values of the SMR, SRR, and 95% CIs in a way that makes them higher than they actually are.

In summary, if more accurate information on population size was used in the analysis, then the values of the SIRs, SMRs, and SRRs would be lower than they were in these results: the incidence and mortality rates in the Glendale study populations might be even lower, in comparison to the rates in the U.S. population, than this analysis indicates.

3. **The analysis might fail to observe a true excess of asbestos-related cancers and disease if the study populations include people who could not have been exposed to asbestos from the processing of vermiculite at the Glendale plant.**

This health statistics review would ideally evaluate the health status of only those people who were exposed to asbestos from the processing of Libby vermiculite at the Glendale plant, assuming that off-site contamination and exposure did occur. The effect of including people who were not exposed to asbestos in the study population is to lessen the ability to see an excess of asbestos-related disease in the population. This happens because the people who were never exposed to asbestos can make the population appear healthier than it would otherwise appear if they were not included in the analysis.

Due to several reasons (such as lack of information on whether asbestos pollution from the Glendale plant occurred, lack of information on how far the asbestos pollution would have traveled in the air, and restrictions on the geographic area for which cancer and mortality statistics are available), it is likely that this health statistics review evaluated the occurrence of asbestos-related cancers and death in a population that included people who were never exposed to asbestos. Therefore, the SIRs, SMRs, SRRs and 95% CIs are likely to be smaller numbers than they would be if unexposed people were not included in the study population. The incidence and mortality rates in the Glendale population might be higher, in comparison to the rates in the U.S. population, if the study populations only included people who exposed to Libby asbestos from the processing of Libby vermiculite at the Glendale plant.

4. **The analysis might fail to observe a true excess of asbestos-related cancers and disease, attributable to vermiculite processing at the Glendale plant if the study periods do not correspond to the years that this excess of disease would be expected to occur.**

The diseases caused by exposure to asbestos take many years to develop. Current knowledge is that lung cancer will develop 20 to 30 years after exposure to asbestos, mesothelioma will develop 30 to 40 years after exposure, and asbestosis will develop 10 to 20 years after exposure. the Glendale plant received shipments of Libby vermiculite between the years 1967 and 1979. Therefore, we would expect that any lung cancer caused by exposure to Libby asbestos would occur between 1987–2009, any mesothelioma caused by exposure to Libby asbestos would occur between 1997–2019, and any asbestosis caused by exposure to Libby asbestos would occur between 1977–1999.

This health statistics review evaluated the incidence rates and mortality rates from asbestos-related diseases between the years 1985–1996 and 1989–1998, respectively. These study periods do not correspond entirely to the years that disease caused by exposure to Libby asbestos is most likely to occur (see Table E–4). Specifically, the study periods precede the years that mesothelioma is expected to occur, and they do not include all of the years that all three disease are expected to occur.

Table E–4. Years that Disease Due to Exposure to Libby Asbestos From Vermiculite Processing at the Glendale Plant Would Be Expected To Occur (Assuming That Hazardous Exposure Occurred), and Number of Study Period Years During Which Exposure-Related Disease Is Expected To Occur.

Disease	**Years during which asbestos-related disease is most likely to occur (based on latency period)**	**Number of years of overlap between the study period and the years that asbestos-related disease is most likely to occur**	
		Cancer Statistics Review (1986–1995)	***Mortality Statistics Review (1989–1998)***
Cancer of the lung and bronchus	1987–2009	9	10
Mesothelioma	1997–2019	0	2
Asbestosis	1977–1999	—	10

5. **The results of the health statistics review can serve as an indicator of community exposure to Libby asbestos only if the study populations include the people who were living near the Glendale plant at the time that Libby vermiculite was processed.**

According to the protocol for this health statistics review, finding a statistically significant elevation in asbestos-related disease in a community would alert CDHS and ATSDR to the possibility that community members might have been exposed to asbestos as a result of the facility's handling or processing of vermiculite from Libby. This interpretation is based on an assumption that the study population consists of people who were exposed to Libby asbestos. Therefore, this interpretation is appropriate only if the study populations include the people who were living near the Glendale plant during the time that Libby vermiculite was processed.

Cancer registry and vital statistics records do not collect information on residential history. Therefore it is not possible to determine whether the people in the study populations lived near the Glendale plant during the years that Libby vermiculite was processed. However, information on population mobility from the U.S. Census can provide some insight into the likelihood that the study populations included the people who were living near the Glendale plant during the years that Libby vermiculite was processed (1967–1979).

According to the 1990 U.S. Census, only 20% of the people residing in census tracts 1881, 3017, and 3023 moved into their home prior to 1979. And, according to the 1990 and 2000 Census, approximately 15%–25% of the people residing in ZIP codes 90039, 91203, and 91204 moved into their home prior to 1979 . Therefore, nearly all of the people in the study populations did not have the potential to be exposed to Libby asbestos, since they moved into their homes after the Glendale plant stopped exfoliating Libby vermiculite.

Summary

The cancer statistics review did not find any evidence that the census tracts 1881, 3017, and 3023 population, or the ZIP codes 90039, 91203, and 91204 population experienced high incidence or mortality rates for asbestos-related diseases during the years 1986–1995 and 1989–1998, respectively. In fact, compared to the U.S. population, the study populations had either the same or lower incidence and mortality rates of lung cancer, mesothelioma, and asbestosis.

Digestive organ cancers have been inconclusively linked to asbestos exposure in previous studies. This analysis found no excess of digestive organ cancers in the census tracts 1881, 3017, and 3023 population, or the ZIP codes 90039, 91203, and 91204 population. In fact, incidence rates were lower in the cancer study population than in the U.S. population during the years 1986-1995.

The mortality statistics review indicated that the ZIP codes 90039, 91203, and 91204 population had either the same or statistically significantly lower rates of death from diseases that could theoretically be worsened by exposure to asbestos, including chronic obstructive pulmonary disease, other diseases of the respiratory system, and diseases of the pulmonary circulation.

Finally, the results for the remaining diseases evaluated in the health statistics review indicate that an excess of asbestos-related disease in this Whittier population is not being obscured by physician misdiagnosis or by discrepancies between the ways that cancer diagnoses are reported to the CCR and SEER.

A very similar protocol to the one used in this health statistics review identified a statistically significant excess of asbestos-related disease in the Libby, Montana, community. If the Glendale study populations were similar to the Libby community in terms of level of exposure to Libby asbestos, population mobility, and other characteristics, then this type of analysis would be expected to also be able to detect a statistically significant excess of asbestos-related disease in the Glendale community.

The Glendale study populations differ from the Libby community in ways that increase the limitations of this type of analysis. Therefore, although the results of this health statistics review could be correctly reflecting that the health of the Glendale community was not impacted by exposure to Libby asbestos, the lack of consistent evidence of disease excess could be due to any or all of the following reasons.

This analysis did not account for the ways in which the Glendale and U.S. populations differ with respect to other risk factors for asbestos-related disease.

The assumptions about the size of the Glendale study populations made the incidence and mortality rates in the Glendale study populations appear more similar to the rates in the U.S. population than they truly are.

The study populations included people who were never exposed to Libby asbestos from the Glendale plant, which also made the incidence and mortality rates in the Glendale study populations appear more similar to the rates in the U.S. population than they truly are

Given the years that exposure to Libby asbestos would have occurred, combined with the amount of time that asbestos-related disease takes to develop, this analysis might be failing to observe an excess of disease or death because this excess of disease has not yet occurred (in the case of mesothelioma) or because the study period does not examine the entire period that disease is expected to occur (in the case of lung cancer and asbestosis).

More important than these limitations is the likelihood that the study populations do not include the people who were living near the Glendale plant during the years that Libby vermiculite was processed. Because the study populations do not appear to include very many people who were potentially exposed to Libby asbestos, the results of this analysis do not serve as a reliable indicator of past community exposure. Therefore, the lack of evidence of high rates of asbestos-related disease during the years 1986–1995 and 1989–1998 in the Glendale study populations does not establish that the community neighboring the W.R. Grace & Company, Glendale plant, was not exposed to Libby asbestos.

Public Health Action Plan

The Public Health Action Plan is a collection of activities intended to ensure that this health statistics review also provides a plan of action to mitigate and to prevent adverse effects on human health resulting from exposure to asbestos from Libby vermiculite. Some activities have already been taken by CDHS or ATSDR. Others activities are either ongoing or planned for the future.

Actions Completed

CDHS conducted a needs assessment with the Los Angeles County Health Officer and Environmental Health Departments, the goals of which were to educate the departments about the vermiculite health statistics review project, to obtain information about the extent and level of stakeholder concerns, to develop an information dissemination plan, and to identify ways CDHS can support local efforts or activities pertaining to the Glendale plant.

CDHS disseminated information materials on consumer products made with Libby vermiculite to increase public awareness of the potential for adverse health effects and ways to reduce or avoid current or future exposure to asbestos from this source.

CDHS briefed the Occupational Health Branch (of CDHS) about the asbestos contamination of Libby vermiculite, the facilities in California that processed this vermiculite, and the potential for workers at these facilities to have been exposed to asbestos.

Information on the potential for and ways to reduce exposure to asbestos in vermiculite consumer products was included in this health consultation and provided to the Alameda County Health Officer and Environmental Health Director.

Ongoing Actions

CDHS will continue to provide technical assistance related to the vermiculite health statistics review to the Los Angeles County Health Officer and Environmental Health Director.

Planned Actions

ATSDR has funded health statistics reviews in 25 states with facilities that received Libby vermiculite. Once all of the results from participating states have been received, ATSDR will compare the SRRs for all the sites examined in order to identify trends that might not be apparent when each facility is evaluated individually. The results of the health statistics reviews will also be evaluated in combination with all information on environmental exposures to asbestos produced by research by the National Asbestos Exposure Review project of ATSDR. ATSDR will distribute the results of these analyses to contributing state health departments and other interested parties.

Using the results of ATSDR's review of health statistics for all vermiculite facilities nationwide, CDHS will conduct follow-up activities with the Los Angeles County Health Officer and Environmental Health Departments. The specifics of these activities will depend on what is learned from the nationwide review.

References

1. Environmental Data Resources. Aerial photography print service for 5440 West San Fernando Road, Los Angeles, CA 90039. Historical aerial photographs from Fairchild (1927, 1940, 1956, 1965), Teledyne (1976), U.S. Geological Survey (1989). Milford, Connecticut: Environmental Data Resources, Inc.; 2004.
2. Bureau of the Census. 1990 Census. US Department of Commerce. Available at: http://www.census.gov.
3. National Weather Service (National Oceanic and Atmospheric Administration). Los Angeles/Oxnard. US Department of Commerce. Available at: http://www.wrh.noaa.gov/lox/climate/climate_intro.php. Accessed October 25, 2006.
4. US Geological Survey. Reconnaissance study of the geology of U.S. vermiculite deposits: are asbestos minerals common constituents? Denver: US Department of the Interior; May 7 2002.
5. Atkinson GR, Rose D, Thomas K, Jones D, Chatfield EJ, Going JE. Collection, analysis and characterization of vermiculite samples for fiber content and asbestos contamination. Prepared for EPA Office of Pesticides and Toxic Substances, Field Studies Branch by Midwest Research Institute. Washington DC: US Environmental Protection Agency; Sept 1982.
6. US Bureau of Mines. Vermiculite. Washington DC: US Department of Commerce, Bureau of Mines (BOM); May 1933.
7. US Bureau of Mines. Vermiculite. Washington DC: US Department of the Interior, Bureau of Mines (BOM); October 1953.
8. Occupational Safety and Health Administration: Introduction to 29 CFR Parts 1910, 1915, 1926, occupational exposure to asbestos. Federal Register 1994 August 10;59:40964-41162.
9. Remedium Group (subsidiary of W.R. Grace). Letter to Barbara Anderson (Agency for Toxic Substances and Disease Registry) from Robert R. Marriam transmitting company documents concerning air sampling/monitoring and waste disposal practices for selected expansion facilities. March 10, 2003.
10. Agency for Toxic Substances and Disease Registry. Health consultation: Western Mineral Products Site, Minneapolis, Hennepin County, Minnesota. Prepared for ATSDR by Minnesota Department of Health. Atlanta: US Department of Health and Human Services; May 2001.
11. Agency for Toxic Substances and Disease Registry. Health consultation: W.R. Grace Dearborn Plant, Dearborn, Wayne County, Michigan. Prepared for ATSDR by Michigan Department of Community Health. Atlanta: US Department of Health and Human Services; Oct 2004.
12. Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos (update). Atlanta: US Department of Health and Human Services; Sept 2001.
13. Lanphear BP, Buncher CR. Latent period for malignant mesothelioma of occupational origin. J Occup Med. 1992;34(7):718-21.
14. Amandus HE, Althouse R, Morgan WK, Sargent EN, Jones R. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part III. Radiographic findings. Am J Ind Med 1987;11(1):27–37.
15. Amandus HE, Wheeler R. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part II. Mortality. Am J Ind Med 1987;11(1):15-26.

16. Amandus HE, Wheeler R, Jankovic J, Tucker J. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part I. Exposure estimates. Am J Ind Med 1987;11(1):1-14.
17. McDonald JC, McDonald AD, Armstrong B, Sebastien P. Cohort study of mortality of vermiculite miners exposed to tremolite. British Journal of Industrial Medicine 1986;43(7):436-44.
18. Peipins LA, Lewin M, Campolucci S, Lybarger JA, Miller A, Middleton D, et al. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana, USA. Environ Health Perspect 2003;111(14):1753-9.
19. Agency for Toxic Substances and Disease Registry. Health consultation: mortality in Libby, Montana (1979-1998). Atlanta: US Department of Health and Human Services; Aug 2002.
20. Lockey JE, Brooks SM, Jarabek AM, Khoury PR, McKay RT, Carson A, et al. Pulmonary changes after exposure to vermiculite contaminated with fibrous tremolite. American Review of Respiratory Disease 1984;129(6):952-8.
21. Wright RS, Abraham JL, Harber P, Burnett BR, Morris P, West P. Fatal asbestosis 50 years after brief high intensity exposure in a vermiculite expansion plant. Am J Respir Crit Care Med April 15, 2002;165(8):1145-9.
22. US Environmental Protection Agency. Report on the peer consultation workshop to discuss a proposed protocol to assess asbestos-related risk. Prepared for EPA Office of Solid Waste and Emergency Response by Eastern Research Group, Inc. Washington DC: EPA; May 30, 2003.
23. Berman DW, Crump KS. Technical support document for a protocol to assess asbestos-related risk (final draft). Prepared for EPA Office of Solid Waste and Emergency Response. Washington DC: EPA; October 2003.
24. Agency for Toxic Substances and Disease Registry. Report on the expert panel on health effects of asbestos and synthetic vitreous fibers: the influence of fiber length. Atlanta: US Department of Health and Human Services; 2003.
25. McDonald JC, McDonald AD. Chrysotile, tremolite and carcinogenicity. Ann Occup Hyg Dec 1997;41(6):699-705.
26. US Environmental Protection Agency. Focused removal assessment report, Sunland Chemical and Harrington Tools properties, 5420-5440 West San Fernando Road, Glendale, CA. Prepared for EPA Region 9 by US Department of Transportation Volpe Center and CDM Federal Programs Corporation. San Francisco, CA: EPA Region 9; June 2001.
27. Agency for Toxic Substances and Disease Registry. World Trade Center response activities close-out report: September 11, 2001–April 30, 2003. Atlanta: US Department of Health and Human Services; May 16 2003.
28. US Environmental Protection Agency. World Trade Center indoor environmental assessment: selecting contaminants of potential concern and setting health-based benchmarks. New York City: EPA Region 2; May 2003.
29. U.S. Environmental Protection Agency: Asbestos-containing materials in schools, final rule and notice. Federal Register 1987 October 30;52:41826-41845.
30. U.S. Environmental Protection Agency: National emission standards for hazardous air pollutants; asbestos NESHAP revision. Federal Register 1990 November 20;55:48415.

31. US Environmental Protection Agency. Memorandum to Superfund National Policy Managers, Regions 1-10, from MB Cook (Director, Office of Superfund Remediation and Technology Innovation, EPA) clarifying cleanup goals and identification of new assessment tools for evaluating asbestos at Superfund cleanups. Washington DC: EPA; August 10, 2004.
32. US Environmental Protection Agency. Memorandum to P Peronard (On-Scene Coordinator, Libby Asbestos Site, EPA Region 8) from CP Weiss (Senior Toxicologist/Science Support Coordinator, Libby Asbestos Site, EPA Region 8) Amphibole mineral fibers in source materials in residential and commercial areas of Libby pose an imminent and substantial endangerment to public health. Denver: EPA; December 20, 2001.
33. US Environmental Protection Agency. Memorandum to J Ackerman (On-Scene Coordinator, EPA Region 8) from AK Miller (Senior Medical Officer and Regional Toxicologist, EPA Region 8) Endangerment Memo: health risks secondary to exposure to asbestos at former Intermountain Insulation facility at 800 South 733 West (SLC1), Salt Lake City, UT. Denver: EPA; March 24, 2004.
34. US Environmental Protection Agency. Priority review level 1: asbestos-contaminated vermiculite. Washington DC: Environmental Protection Agency; June 1980.
35. US Environmental Protection Agency. Pollution report for the Harrington Tool vermiculite site, Glendale (Los ANgeles), California. San Francisco, CA: EPA Region 9; June 3, 2002.
36. Anderson HA, Lilis R, Daum SM, Selikoff IJ. Asbestosis among household contacts of asbestos factory workers. Ann N Y Acad Sci 1979;330:387-99.
37. Powell C, Cohrssen B. Asbestos. In: Bingham E, Cohrssen B, Powell C, eds. Patty's toxicology. 5th ed.: John Wiley & Sons, Inc.; 2001.
38. Agency for Toxic Substances and Disease Registry. Health consultation: Vermiculite Northwest, Spokane, Spokane County, Washington. Prepared for ATSDR by Washington State Department of Health. Atlanta: US Department of Health and Human Services; July 2004.
39. Merchant JA. Human epidemiology: a review of fiber type and characteristics in the development of malignant and nonmalignant disease. Environmental Health Perspectives 1990;88:287-93.
40. Albin M, Johansson L, Pooley FD, Jakobsson K, Attewell R, Mitha R. Mineral fibres, fibrosis, and asbestos bodies in lung tissue from deceased asbestos cement workers. British Journal of Industrial Medicine 1990;47(11):767-74.
41. Green FH, Yoshida K, Fick G, Paul J, Hugh A, Green WF. Characterization of airborne mineral dusts associated with farming activities in rural Alberta, Canada. International Archives of Occupational & Environmental Health 1990;62(6):423-30.
42. Hasanoglu HC, Gokirmak M, Baysal T, Yildirim Z, Koksal N, Onal Y. Environmental exposure to asbestos in eastern Turkey. Archives of Environmental Health 2003;58(3):144-50, 2003 Mar.
43. anonymous. Health effects of tremolite. This official statement of the American Thoracic Society was adopted by the ATS Board of Directors, June 1990. Am Rev Resp Disease 1990;142(6 Pt 1):1453-8.

44. Comba P, Gianfagna A, Paoletti L. Pleural mesothelioma cases in Biancavilla are related to a new fluoro-edenite fibrous amphibole. Archives of Environmental Health 2003;58(4):229-32.
45. Maynard C. Asbestos problems in Montana and California.[comment].46A, 2004 Feb 1.
46. Dodson RF, O'Sullivan M, Brooks DR, Hammar SP. Quantitative analysis of asbestos burden in women with mesothelioma. American Journal of Industrial Medicine 2003 Feb 2003;43(2):188-95.

	U.S. incidence rate for all cancers 1986–1995		# people in census tracts 1881, 3017, and 3023 1986–1995		Expected # in census tracts 1881, 3017, and 3023, 1986–1995
STEP 1					
Females					
0 to 4	0.000188	X	9,020	=	1.7
5 to 9	0.000097	X	6,750	=	0.7
10 to 14	0.000116	X	6,100	=	0.7
15 to 19	0.000205	X	7,020	=	1.4
20 to 24	0.000351	X	10,080	=	3.5
25 to 29	0.000605	X	12,400	=	7.5
30 to 34	0.000948	X	10,460	=	9.9
35 to 39	0.001601	X	9,050	=	14.5
40 to 44	0.002631	X	7,130	=	18.8
45 to 49	0.004182	X	5,380	=	22.5
50 to 54	0.005868	X	4,390	=	25.8
55 to 59	0.008014	X	3,770	=	30.2
60 to 64	0.010734	X	3,760	=	40.4
65 to 69	0.013577	X	3,710	=	50.4
70 to 74	0.016334	X	3,170	=	51.8
75 to 79	0.018378	X	2,960	=	54.4
80 to 84	0.019683	X	2,250	=	44.3
85 & up	0.019640	X		=	
Males			3,010		59.1
0 to 4	0.000216	X	2,610	=	2.0
5 to 9	0.000123	X	1,950	=	0.9
10 to 14	0.000124	X	1,540	=	0.8
15 to 19	0.000210	X	1,600	=	1.5
20 to 24	0.000333	X	2,440	=	3.6
25 to 29	0.000573	X	5,330	=	7.6
30 to 34	0.000871	X	4,430	=	10.8
35 to 39	0.001191	X	3,340	=	11.9
40 to 44	0.001630	X	2,610	=	11.9
45 to 49	0.002697	X	1,890	=	14.1
50 to 54	0.004991	X	1,140	=	21.1
55 to 59	0.008856	X	640	=	32.2
60 to 64	0.014763	X	560	=	50.8
65 to 69	0.022620	X	550	=	64.0
70 to 74	0.030244	X	310	=	55.0
75 to 79	0.035267	X	180	=	59.2
80 to 84	0.038441	X	230	=	47.7
85 & up	0.037822	X	40	=	37.8
Total number of expected cases in census tract:					***870.5***
STEP 2					

$$\textbf{SIR} = \frac{\textbf{582}}{\textbf{870.5}} = \textbf{0.67}$$

Addendum 1: Standardized Incidence Ratio

The standardized incidence ratio (SIR) is a measure that compares the incidence rate of disease in two populations. In this health statistics review the SIR compares, for the time period 1986 through 1995, the number of people who were diagnosed with a type of cancer while residing in census tract 1881, 3017, and 3023 and the number of people expected to be diagnosed with cancer if the incidence rate of cancer in the cancer study population was the same as the incidence rate in the U.S. population. The SIR was calculated to account for ways in which census tract 1881, 3017, and 3023 and U.S. populations differ in terms of age and sex.

The SIR is calculated in two steps:

Step 1: the expected number is calculated by 1) multiplying the incidence rate in various age and sex groups in the U.S. population by the number of people in those age and sex groups in the cancer study population; then 2) summing the products to obtain the total number of expected cases in the cancer study population.

Step 2: The SIR is calculated by dividing the actual number of people who were diagnosed with cancer by the expected number.

These steps are demonstrated at left for all types of cancer.

	ZIP Codes 90039, 91203, and 91204 mortality rate, all cancers, 1989–1998		# people in the U.S. 1989–1998		Expected # deaths in the U.S. 1989–1998
STEP 1					
Females					
0 to 4	0.000000	X	93,966,244	=	0.0
5 to 9	0.000000	X	91,867,322	=	0.0
10 to 14	0.000069	X	89,304,231	=	6,154.7
15 to 19	0.000000	X	87,811,833	=	0.0
20 to 24	0.000040	X	90,427,466	=	3,653.6
25 to 29	0.000034	X	98,755,306	=	3,309.5
30 to 34	0.000188	X	108,681,120	=	20,444.2
35 to 39	0.000200	X	107,902,167	=	21,537.4
40 to 44	0.000213	X	98,780,341	=	21,039.5
45 to 49	0.000767	X	82,737,629	=	63,456.6
50 to 54	0.000979	X	67,120,643	=	65,712.5
55 to 59	0.001781	X	57,368,622	=	102,155.9
60 to 64	0.002681	X	54,716,238	=	146,706.9
65 to 69	0.004048	X	54,396,949	=	220,206.5
70 to 74	0.005317	X	48,337,651	=	257,010.0
75 to 79	0.007271	X	39,220,867	=	285,157.7
80 to 84	0.011647	X	27,563,804	=	321,024.2
85 & up	0.007388	X	24,880,271	=	183,812.0
Males					
0 to 4	0.000096	X	98,444,382	=	9,493.2
5 to 9	0.000104	X	96,375,416	=	9,992.3
10 to 14	0.000060	X	93,779,769	=	5,598.8
15 to 19	0.000108	X	92,727,275	=	9,970.7
20 to 24	0.000039	X	93,916,511	=	3,661.5
25 to 29	0.000088	X	99,300,884	=	8,782.5
30 to 34	0.000091	X	107,836,073	=	9,836.1
35 to 39	0.000105	X	106,638,555	=	11,209.4
40 to 44	0.000459	X	96,528,396	=	44,340.1
45 to 49	0.001119	X	79,706,353	=	89,223.5
50 to 54	0.002320	X	63,474,519	=	147,283.7
55 to 59	0.002413	X	52,786,640	=	127,367.2
60 to 64	0.004681	X	48,333,937	=	226,264.4
65 to 69	0.007917	X	44,815,676	=	354,813.5
70 to 74	0.011311	X	36,773,021	=	415,924.7
75 to 79	0.015584	X	26,482,551	=	412,715.1
80 to 84	0.014961	X	15,345,068	=	229,571.9
85 & up	0.015640	X	9,774,311	=	152,868.4
Total number of expected deaths in US:					***3,990,298.0***
STEP 2					

$$\textbf{SRR} = \frac{3{,}990{,}298.0}{5{,}259{,}810} = 0.76$$

Addendum 2: Standardized Rate Ratio

The standardized rate ratio (SRR) is a measure that compares the incidence rate or the mortality rate for a disease in two populations. For the cancer statistics review, the SRR compares the number of people in the U.S. who were diagnosed with a type of cancer, and the number of people expected to be diagnosed if the incidence rate in the U.S. population was the same as the incidence rate in the cancer study population. For the mortality statistics review, the SRR compares the number of people in the U.S. who died from a disease and the number of people expected to die if the mortality rate in the U.S. population was the same as the mortality rate in the mortality study population.

The SRR is calculated in a manner that accounts for ways in which the study populations and the U.S. population differ in terms of age and sex. The SRR is calculated in two steps:

Step 1: the expected number of cases or deaths in the U.S. population is calculated by 1) multiplying the incidence or mortality rate in various age and sex groups in the study population by the number of people in those age and sex groups in the U.S. population, then 2) summing the products to obtain the total number of expected cases or deaths in the U.S. population.

Step 2: The SRR is calculated by dividing the expected number of cases or deaths (calculated in step 1) by the actual number of cases or deaths that occurred. These steps are demonstrated at right for the mortality rate of all types of cancer.

Addendum 3: Standardized Mortality Ratio

The standardized mortality ratio (SMR) is a measure that compares the mortality rate for a disease in two populations. In this health statistics review, the SMR compares, for the time period 1989 through 1998, the number of people who died from a disease while residing in ZIP Code 90039, 91203, and 91204 to the number of people expected to die, if the mortality rate for the disease in the mortality study population was the same as the mortality rate for the disease in the U.S. population. The SMR was calculated in a manner that accounts for ways in which the ZIP Code 90039, 91203, 91204 and U.S. populations differ in terms of age and sex.

The SMR is calculated in two steps:

Step 1: the expected number of deaths is calculated by 1) multiplying the mortality rate in various age and sex groups in the U.S. population by the number of people in those age and sex groups in the mortality study population; then 2) summing the products to obtain the total number of expected deaths in the mortality study population.

Step 2: The SMR is calculated by dividing the actual number of deaths that occurred by the expected number (calculated in step 1).

These steps are demonstrated at left for death from all types of cancer.

	U.S. mortality rate for all cancers, 1989–1998		# people in ZIP Codes 90039, 91203, and 91204 1989–1998		Expected # deaths in ZIP Code 90039, 91203, and 91204
STEP 1					
Females					
0 to 4	0.000027	X	20,800	=	0.6
5 to 9	0.000026	X	14,810	=	0.4
10 to 14	0.000024	X	14,510	=	0.4
15 to 19	0.000033	X	16,800	=	0.6
20 to 24	0.000045	X	24,750	=	1.1
25 to 29	0.000082	X	29,840	=	2.4
30 to 34	0.000162	X	26,580	=	4.3
35 to 39	0.000319	X	25,050	=	8.0
40 to 44	0.000591	X	18,780	=	11.1
45 to 49	0.001075	X	16,950	=	18.2
50 to 54	0.001851	X	14,300	=	26.5
55 to 59	0.002916	X	10,670	=	31.1
60 to 64	0.004336	X	10,070	=	43.7
65 to 69	0.005933	X	9,140	=	54.2
70 to 74	0.007832	X	9,780	=	76.6
75 to 79	0.009567	X	8,390	=	80.3
80 to 84	0.011546	X	4,980	=	57.5
85 & up	0.014049	X	7,580	=	106.5
Males					
0 to 4	0.000031	X	20,740	=	0.7
5 to 9	0.000032	X	19,290	=	0.6
10 to 14	0.000032	X	16,750	=	0.5
15 to 19	0.000047	X	18,600	=	0.9
20 to 24	0.000064	X	25,650	=	1.7
25 to 29	0.000090	X	33,920	=	3.1
30 to 34	0.000145	X	32,890	=	4.8
35 to 39	0.000252	X	28,540	=	7.2
40 to 44	0.000498	X	21,770	=	10.8
45 to 49	0.001033	X	16,080	=	16.6
50 to 54	0.002057	X	13,360	=	27.5
55 to 59	0.003744	X	11,190	=	41.9
60 to 64	0.006262	X	10,040	=	62.9
65 to 69	0.009319	X	8,210	=	76.5
70 to 74	0.012953	X	5,570	=	72.1
75 to 79	0.016628	X	3,850	=	64.0
80 to 84	0.021582	X	3,810	=	82.2
85 & up	0.027371	X	2,110	=	57.8
Total number of expected deaths:					***1055.0***
STEP 2					

$$\textbf{SMR} = \frac{\textbf{782}}{\textbf{1055.0}} = \textbf{0.74}$$