Health Consultation

FORMER ZONOLITE COMPANY/
W.R. GRACE FACILITY – ST. LOUIS

1705 SULPHUR AVENUE
CITY OF ST. LOUIS, MISSOURI

EPA FACILITY ID: MON000703779

AUGUST 16, 2006

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

Health Consultation: A Note of Explanation

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

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

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Prepared by:

Missouri Department of Health and Senior Services
Division of Community and Public Health
Bureau of Environmental Epidemiology
under cooperative agreement with the
Agency for Toxic Substances and Disease Registry

Foreword:
ATSDR National Asbestos Exposure Review

Vermiculite, a naturally occurring mineral, was mined and processed in Libby, Montana, from the early 1920s until 1990. We now know that this vermiculite, which was shipped to many locations 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 exposure to asbestos from processing operations. Determining the extent and the hazard potential of commercial or consumer use of products such as vermiculite attic insulation or vermiculite gardening products made with contaminated vermiculite is beyond the scope of this project. Information has been developed for consumers of vermiculite products by the U.S. Environmental Protection Agency (EPA), ATSDR, and the National Institute for Occupational Safety and Health (NIOSH). This information is available at www.epa.gov/asbestos/insulation.html.

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

Phase 1: ATSDR has selected 28 sites for the first phase of reviews based on the following criteria:

- EPA 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.

TABLE OF CONTENTS

STATEMENT OF ISSUES AND BACKGROUND

The Missouri Department of Health and Senior Services (DHSS) prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). The objectives of this document are to summarize information about the former Zonolite/W.R. Grace site in St. Louis, Missouri and to evaluate the public health implications of any potential past, present, and future pathways of human exposure to asbestos-contaminated vermiculite ore from Libby, Montana.

BACKGROUND

The former Zonolite/W.R. Grace-St. Louis facility (referred to as the St. Louis facility in this health consultation) consists of an approximately 45,000-square-foot metal building located on an approximately one and a half-acre lot at 1705 Sulphur Avenue in St. Louis, Missouri (1). For the location of the site, see Figure 1 in Appendix A. The St. Louis facility is one of the former vermiculite processing plants that received asbestos-contaminated vermiculite ore from Libby, Montana. The site is located in a mixed industrial and residential area of St. Louis with major railroad lines north and south of the property (See Figure 1 and 2). Population data are discussed in the Demographic Section. Two main highway thoroughfares are situated near the site. Manchester Road is north of the railroad tracks and an elevated portion of Hampton Avenue is to the west of the site. Sulphur Avenue is to the east and fronts the site (See Figure 3). Further to the south of the site and the railroad tracks are the River Des Peres drainage ditch and US Highway 44. Southwest of the site is the neighborhood known as “The Hill”. The neighborhoods of Cheltenham and Clayton-Tamm are closest to the site at less than a quarter of a mile to the north and west, respectively. The neighborhoods of Franz Park and Hi-Pointe are located further west and northwest of the site. These four neighborhoods together are sometimes referred to as “Dogtown”, a name that dates back to the early 1900s (2). These are all well established neighborhoods that date back to the late 1800s and early 1900s. Closer to the site is the former Gratiot Grade School located less than one-tenth mile northwest of the former St. Louis facility. Meteorological data from the St. Louis International Airport suggests that the area’s major prevailing winds are from the west to northwest toward “The Hill”. The other significant prevailing wind direction is from the south to southeast toward the neighborhoods of Cheltenham and Clayton-Tamm (See Figure 4). The airport is approximately 14 miles to the northwest of the site; therefore actual wind conditions at the site could vary because of local topography and other factors.

Zonolite Insulation Company (Zonolite) purchased the property at 1705 Sulphur Avenue in 1944 (3,4). Until 1956, Zonolite’s main office address was listed as 5100 Manchester Road. In September 2003, DHSS conducted an informal site visit of the building at 5100 Manchester Road. No evidence of raw or processed vermiculite material or associated asbestos materials was found inside or outside the building. There was no equipment, such as a furnace, silo platform, etc., associated with the building to indicate that it was ever used for exfoliating vermiculite. Therefore, this health consultation will focus on the exfoliating facility at 1705 Sulphur Avenue. After 1956, Zonolite's address was listed as 1705 Sulphur Avenue (3). When the facility on Sulphur Avenue actually started receiving and processing (exfoliating or popping) Libby vermiculite is not known. US Environmental Protection Agency (EPA) records indicate that 139,460 tons of vermiculite ore were received and processed at the facility from January 1966 to September 1988 (unpublished information from EPA's database of W.R. Grace invoices). The company first started advertising vermiculite products in the 1954 Greater St. Louis Telephone Directory. The possibility exists that Libby vermiculite was processed at the Sulfur Avenue site before 1966 since the site was purchased in 1944. Because the production history is incomplete, the actual amount of vermiculite ore processed could be much greater than EPA records indicate.

In the early 1960s, Zonolite changed its name to the Sulphur Avenue Corporation. In 1970, the property was leased to W.R. Grace who continued processing Libby vermiculite (1,4). W.R. Grace is believed to have continued to process Libby vermiculite until late 1988, but continued their lease on the facility until 1990. During that period of time they removed the processing furnaces, storage silos, and completed a wash down of the facility. On August 30, 1990, W.R. Grace reportedly performed a clearance air sampling of the facility. Eight-hour engineering samples were collected from stationary air pumps at four locations inside the facility (including the furnace area) along with a background sample from outside the building. These confirmation air samples were collected from stationary pumps and, along with a field blank, were analyzed presumably by phase contrast microscopy (PCM). Insufficient information is available to determine if aggressive sampling was performed (e.g., if the air and dust surrounding the pump were disturbed to re-suspend residual fibers during sampling). Laboratory sample results indicated no visible fibers were detected in any of the samples (unpublished information from US EPA's database of W.R. Grace documents).

The St. Louis facility generally operated 24 hours a day, 7 days a week. Shift times varied, with the normal being three – 8 hour shifts, but could range from two – 12 hour shifts to two – 8 hour shifts, depending on the demand for the products (personal conversation with a former employee and unpublished information from US EPA's database of W.R. Grace documents). Available information does not give a reliable estimate of the number of employees who worked at any one time or the total number of employees, but a memo requesting copies of chest X-rays, lists 14 employees at the St. Louis facility (unpublished information from US EPA's database of W.R. Grace documents).

Former workers and residents reported that operations at the St. Louis facility were quite dusty during the early years. Dust from the facility is reported to have accumulated on outside surfaces and even infiltrated into nearby homes (telephone conversations with former workers and community members). Asbestos fibers may have been incorporated in the dust emitted from the facility, but are not expected to have traveled far from the facility.

Raw vermiculite ore and waste material were piled outside the facility. Children played on the piles and in the railroad cars around the site (telephone conversations with community members).

This probably took place until the storage bins were installed and unloading became automated with “belly dump” railroad cars. Workers were not provided uniforms until the early 1980s, and most likely would have carried some of the asbestos contaminated dust home on their clothes. Showers were provided at the facility, but were not always used prior to the early 1980s when it became required. Dust masks were provided, but reports vary on the amount of usage (personal conversation with former employees).

Vermiculite

Vermiculite is a general term for a group of platy (layered) minerals that form from the weathering of micas by groundwater. They undergo a distinctive, prominent, accordion-like unfolding and expansion when heated to between 800° and 1,100° Centigrade (°C), depending on the composition and content of the vermiculite-bearing material. After heat expansion, the vermiculite material is very lightweight and possesses fire- and sound-insulating properties (5). See Figure 5, for examples of vermiculite.

Asbestos

Vermiculite ore mined in Libby, Montana was contaminated with naturally occurring asbestos. Asbestos is a general name for a group of silicate minerals consisting of thin, separable fibers in a parallel arrangement that are strong, heat resistant, and chemically inert. Asbestos minerals fall into two classes, serpentine and amphibole. The serpentine asbestos group includes chrysotile and is the predominant type of asbestos used commercially. Serpentine asbestos fibers are long, flexible, crystalline fibers that have high tensile strength and are resistant to alkalies (6).

Amphibole asbestos minerals are stiff, brittle, and shaped like rods or needles. Like all asbestos, amphibole asbestos fibers are friable (crumble easily) and can become airborne. The amphibole group of asbestos minerals has a relatively high iron content compared to chrysotile, giving them a higher durability or biopersistence in living tissue and thus a higher carcinogenic potential (ability to cause cancer). Amphibole minerals regulated as asbestos by OSHA include the classes of: fibrous tremolite, actinolite, anthophyllite, crocidolite, and amosite. However, other amphibole minerals, including winchite, richterite, and others, can exhibit fibrous asbestiform properties (6).

Individual asbestos fibers are too small to be seen without a microscope or other laboratory instruments. However, asbestos can sometimes be seen when many fibers are still joined together (“as bundles”). Asbestos fibers do not have any detectable odor or taste. Although individual asbestos fibers can easily be suspended in the air, they do not move through soil. They do not dissolve in water or evaporate and are resistant to heat, fire, and chemical and biological degradation. Therefore, the fibers are generally not broken down and can remain in the environment for long periods of time (6). For more information about asbestos, methods of measuring asbestos, asbestos health effects and toxicity, and current standards, regulations, and recommendations for asbestos, see *Asbestos Overview* in Appendix B.

Raw Materials

Most of the vermiculite ore used at the St. Louis facility is believed to have originated from W.R. Grace's mine in Libby, Montana. Reportedly, the St. Louis facility also received some vermiculite ore from W.R Grace's mine in South Carolina (personal conversation with a former employee and unpublished information from US EPA's database of W.R. Grace documents). Vermiculite from W.R. Grace's South Carolina mine reportedly contains less than 1% tremolite and actinolite asbestos by mass (7). Because most of the vermiculite ore originated from the Libby mine and contains a higher concentration of asbestos than the South Carolina ore, this health consultation will focus on the Libby vermiculite ore.

The vermiculite mined at Libby contains amphibole asbestos, with a characteristic composition that includes winchite, richterite, and tremolite as defined by Leake et al., 1997 (8,9); this characteristic material will be referred to as Libby amphibole asbestos (Libby asbestos). In an earlier EPA report, the percentage of tremolite and actinolite asbestos found in the vermiculite ore from Libby, Montana varied in the different grades. Libby grade No. 1 ranged from 4% to 6% tremolite and actinolite asbestos by mass; Libby No. 2 ranged from 4% to 7%; Libby No. 3 ranged from less than 2% to 4%; and Libby No. 4 ranged from 0.3% to 1% (7). Zonolite/W.R. Grace in St. Louis is known to have received No. 1, 3, and 4-grade vermiculite ore from Libby (unpublished information from US EPA's database of W.R. Grace documents). For more information on asbestos see *Asbestos Overview* in Appendix B.

Exfoliating Process

Vermiculite ore was processed at Libby and other exfoliating facilities throughout the country, including the St. Louis facility. Until approximately 1972, the St. Louis facility received ore from Libby, Montana in railroad boxcars. The ore was unloaded with a front loader and stacked in piles (conversation with a former worker). After 1972, belly dump railroad cars were used and the ore was conveyed into four storage silos (conversation with a former worker). Remains of a belly dump pit, a concrete ramp, and silo anchoring bolts remain in the unloading area.

Similar to other vermiculite processing facilities, ore was moved from the storage silos into a furnace where it was heated to around 800 °C, causing the vermiculite to expand or exfoliate. A stoner machine was used to separate the expanded vermiculite from unexpanded ore or "stoner rock". The expanded vermiculite was used to make a variety of products. Stoner rock was discarded as waste, and is referred to in this document as waste rock. Historic W.R. Grace documents estimate that approximately 1 ton of waste rock was generated for every 6.7 tons of vermiculite processed (unpublished information from US EPA's database of W.R. Grace documents). From the known 139,460 tons of ore processed at the St. Louis facility between 1966 and 1988, approximately 20,815 tons of waste rock would have been generated. Considering that the facility exfoliated vermiculite before 1966, the actual amount of waste rock generated may be much higher. W.R. Grace records indicate that waste rock contained between

2% to 10% asbestos. See Figure 6 for an example of waste rock and asbestos. Records are not available to determine the exact disposal location of the waste rock from the St. Louis facility. Reportedly, waste rock may have been dumped outside the building where it was spread out and used as fill or given away (conversation with a former worker). It may also have been used as fill in the vicinity of the current Hampton Street Overpass (conversation with a former worker). According to available information, waste rock was placed in dumpsters from the early 1970s and in later years was bagged and wetted before being placed in dumpsters. The dumpsters were reportedly then hauled to landfills (conversation with a former worker). Currently, there are no obvious signs that indicate waste rock was dumped around the site, used as fill at the site, or is present in the nearby community. The areas around the building are presently asphalted except for the north side, which is grass covered and the area under the Hampton Bridge has a soil cover.

Because stricter air emissions were required under the Clean Air Act, particulate-control technologies were likely installed in the 1970s. To lower air emissions from the plant, a bag house may have been part of the equipment makeup. The types and dates of installation of the different air pollution control devices are not known for the St. Louis plant, but are expected to be similar to other exfoliation plants.

Vermiculite-containing products that the Zonolite Company listed for sale in 1954 consisted of home (attic) insulation, Zonolite Plaster Aggregate, and Zonolite Concrete Aggregate (10). Zonolite listed similar vermiculite products for sale in 1966, in addition to Perlite (an aggregate for plaster). Non-vermiculite products included glass fiber products and Zonolite Dyfoam products. After W.R. Grace took over the operation, products listed for sale in 1973 and 1974, included similar vermiculite products, plus Mono Kote (a fireproofing material that contained added chrysotile asbestos). It is not known if Mono Kote was manufactured at the St. Louis facility, but W.R. Grace soon discontinued the product. Non-vermiculite building products listed for sale included such items as glass fiber, Dyfoam products, Ventboard, Thermo Stud, and Tufhide (unpublished information from US EPA's database of W.R. Grace documents). While most of these products bind the asbestos in a hard matrix and would only release it if abraded (e.g., by sanding) or broken up, attic insulation leaves asbestos contamination loose to become airborne if disturbed.

Worker Protection

In exfoliating facilities, including the St. Louis facility, the level of dust varied within the plant depending on the operation being performed. Until approximately 1980, the St. Louis facility was reported as being extremely dusty with material from the processing procedure and punctured bags lying on the floor (conversation with a former employee). This employee also reported that hygienic conditions inside the facility improved tremendously after 1980.

To protect workers from exposure to harmful levels of asbestos, the Occupational Safety and Health Administration (OSHA) regulates the amount of asbestos fibers in the air that workers breathe during their workday. OSHA first regulated worker asbestos exposure in 1971 at 12 fibers per cubic centimeter (f/cc) of air. Before 1971, asbestos air concentrations at the St. Louis facility are unknown. OSHA lowered the level in 1972 to 2 f/cc of air as a maximum permissible exposure limit (PEL) time weighted average (TWA). From 1976 to 1986, limited available workplace air sampling data showed that asbestos levels at the St. Louis facility were usually below the regulated 2 f/cc level, but asbestos was also detected above the regulated level under normal operations and in instances of equipment problems. The maximum asbestos level found in the limited sampling data was 8.41 f/cc. Equipment problems are listed on the sampling sheet as the likely cause for the asbestos level being this high. In 1986, OSHA lowered the TWA PEL by an order of magnitude to 0.2 f/cc, and then again to the present level of 0.1 f/cc. The only available air sampling data found after the PEL was lowered in 1986 to 0.2 f/cc was a sample at 0.005 f/cc, indicating that for this one sample the facility was able to achieve compliance under the new regulations (unpublished information from US EPA's database of W.R. Grace documents). Intermittent use of personal protection equipment (masks) by the workers seems to have been the norm (unpublished information from US EPA's database of W.R. Grace documents and personal conversations with former employees). After the early 1980s, workers were provided uniforms and required to shower before leaving work (conversation with a former worker).

Demographics

The neighborhoods surrounding the facility are historic, well established, and stable. This includes the neighborhoods of Cheltenham, Clayton-Tamm, Hi-Pointe, and Franz Park situated in the area north and west (also known as "Dogtown") of the site, and "The Hill" southeast of the site. Most of the residences are located on small lots with paved driveways and sidewalks. English, French, Irish, German, and Italian immigrants settled in these neighborhoods around the turn of the 20th Century. There is evidence the area was inhabited prior to the 1904 World's Fair held in St. Louis. After the fair, the population in this area increased. Some reports indicate that the first business in the area was a clay/brick factory that opened in 1857 on Manchester Road (2).

During a portion of the St. Louis facility's years of operation, the Gratiot Grade School at 1615 Hampton Avenue was operational. The school is located less than one-tenth mile northwest of the facility, just across the railroad tracks and Manchester Avenue (See photograph 1-3). Classes were conducted at the school from 1882 until 1975. The school building was later used for continuing education programs. During the years 1956-1975, while the St. Louis facility was known to be in operation, the school averaged 8 teachers and 252 students from kindergarten through the eighth grade (11).

According to 1990 census data calculations, approximately 13,609 people lived within one mile of the facility (See Figure 2). Of this population, 95.7% were white, 2.7% were black, and the remaining population was of two races or more (12). Within census tracts 1036, 1039, 1041, 1042, 1045, 1121, and 1135, encompassing a slightly larger area than one mile surrounding the site, the total population in 1990 was 20,112. Using the same census tracts to analyze 2000 census data, the total population was 18,088 (13), indicating that the population around the site had declined between 1990 and 2000.

Site Environmental Data

In 2000, EPA had the Ecology and Environment, Inc. (E&E) Superfund Technical Assessment and Response Team conduct a removal assessment for six vermiculite sites in EPA Region VII. The Zonolite/W.R. Grace site in St. Louis was one of those sites. According to the E&E report, no visible vermiculite was found within the building, but small traces were found in the soil and debris along the railroad spur north of the building. Two composite samples (multiple samples combined) were taken from the railroad spur. One sample was analyzed using Polarized Light Microscopy (PLM) and the other with transmission electron microscopy (TEM). Both methods found trace amounts of asbestos equal to or less than 1% by volume (14). TEM yields higher magnification and greater sensitivity than PLM, allowing the detection and characterization of smaller fibers (See Appendix B). The E&E removal assessment describes what appears to be the 1705 Sulphur Avenue site, but both the document and map report 5100 Manchester Road as the location that was sampled. Telephone conversations with the EPA on-scene coordinator assured us that the samples were taken at 1705 Sulphur Avenue and the wrong address was inadvertently cited in the report.

Vermiculite Exfoliating Facility Modeling

In 1985, EPA released a report titled *Exposure Assessment for Asbestos-Contaminated Vermiculite* that included air modeling of vermiculite exfoliating facilities from the early 1980s. The releases from a “model” exfoliation plant were evaluated with meteorological conditions that were based on St. Louis, Missouri wind rose data. Because of data limitations, numerous assumptions were made in the model that may overestimate the actual exposure to nearby residents (7). However, the results of the model support the concept that plant emissions could result in airborne asbestos fibers in areas adjacent to the site.

Asbestos Overview

See *Asbestos Overview* in Appendix B for information about asbestos, methods of measuring asbestos, asbestos health effects and toxicity, and current standards, regulations, and recommendations for asbestos.

Site Visit

On September 18, 2002, ATSDR and DHSS personnel conducted a site visit at the former St. Louis facility (See Figure 3 and photographs). The current tenant, L & L Insulation & Supply Company, is a supplier of fiberglass insulation and other miscellaneous insulation products. The site is easily accessible with no fencing around the property. West of the facility is the Hampton Avenue overpass. The area under the overpass is used for parking semi trailers. The remains of a former railroad spur exist next to the building on the north with a railroad car belly dump area. ATSDR staff found unprocessed vermiculite and asbestos in a small area (approximately 20 feet by 20 feet) of soil next to the former silo area and railroad car belly dump area. Smaller flakes of vermiculite were found among the railroad ballast in the former spur near the unloading area. Other than the soil and railroad area, the property around the building is paved. The manager stated that employees did not use the unpaved area. This was evident from tall grass and weeds being present in the area. The unloading area was overgrown with small trees and the former railroad spur next to the building had tall grass and weeds. No piles of vermiculite or waste rock were observed. The nearest residences are less than a quarter of a mile from the site, with the former Gratiot Grade School being located diagonally across Manchester Road (See Photograph 2).

A windshield investigation (drive-though observation) was also carried out in the neighborhood around the site on September 18, 2002. Additional windshield investigations and walking tours of the neighborhood were conducted at later dates. A limited number of interviews were also conducted. One purpose of the site visits was to determine if waste rock had been used in the community. Based on these investigations and interviews, and the fact that no waste rock was observed in the community, it is unlikely that it was commonly used here; however, the possibility does still exist.

DISCUSSION

The W.R. Grace facility-St. Louis is known to have processed at least 139,460 tons of vermiculite ore that originated from the Libby, Montana mine and other sources. The vermiculite ore from Libby was contaminated with asbestos. Studies conducted in the Libby community indicate health impacts are associated with asbestos exposure. The findings at Libby provided the impetus for investigating this site, as well as other sites across the nation that received asbestos-contaminated vermiculite from the Libby mine. The site investigation at the St. Louis facility is part of a national effort to identify and evaluate potential asbestos exposures that may have occurred at these other sites. However, it is important to recognize that the asbestos exposures documented in the Libby community are in many ways unique and will not collectively represent possible exposures at other sites that processed or handled Libby vermiculite.

Summary of Asbestos Facts and Risks

Most inhaled asbestos fibers are expelled, but some can become lodged in the lungs and remain there throughout life. Fibers can accumulate and cause scarring and inflammation; enough scarring and inflammation can affect breathing and lead to disease. The following are basic facts about health effects and risks from asbestos exposure (15):

- People are more likely to experience asbestos-related disorders when they are frequently exposed to high concentrations of asbestos, particularly when that exposure occurs over long periods of time.
- Inhaling longer, more durable asbestos fibers (such as tremolite and other amphiboles) contributes to the severity of asbestos-related disorders.
- Exposure to asbestos, increases the likelihood of lung cancer, mesothelioma (cancer of the pleural membrane that cover the lungs and line the chest cavity), and non-malignant lung conditions such as asbestosis, and changes in the lung pleura.
- Changes in the pleura such as thickening, plaques, calcification, and fluid around the lungs (pleural effusion), may be early signs of asbestos exposure. Pleural effusion can be an early warning sign for mesothelioma.
- Most cases of asbestosis, lung cancer, or mesothelioma in workers occurred 15 years or more after the person was first exposed to asbestos.
- Mesothelioma has been diagnosed in asbestos workers, family members, and residents who live close to asbestos mines.
- Health effects from asbestos exposure may continue to progress even after exposure ceases.
- Smoking, together with exposure to asbestos, greatly increases the likelihood of lung cancer.

Health Risks of Asbestos Exposure

Chronic exposure to asbestos may increase the risk of lung cancer, mesothelioma, and nonmalignant lung and pleural disorders. Evidence in humans comes from epidemiologic studies, as well as numerous studies of workers exposed to asbestos in a variety of occupational settings. Amphibole asbestos exposure has been associated with an increased incidence of disease in vermiculite miners and millers from Libby, Montana. This evidence is supported by reports of increased incidences of nonmalignant respiratory diseases, lung cancer, and mesothelioma in villages in various regions of the world that have traditionally used tremolite-asbestos whitewashes in homes or have high surface deposits of tremolite asbestos, as well as by results from animal studies (15).

Risk Factors

Various factors determine how exposure to asbestos affects an individual (15):

- Exposure concentration - what was the concentration of asbestos fibers?
- Exposure duration - how long did the exposure time period last?
- Exposure frequency - how often during that time period was the person exposed?
- Size, shape, and chemical makeup of asbestos fibers:

When long and thin fibers reach the lower airways and alveolar regions of the lung, they may be retained in the lung longer, and thus are more toxic than short and wide fibers or particles. However, short, thin fibers, may also play a role in the pathogenesis of asbestos illnesses. Fibers of amphibole asbestos such as tremolite asbestos, actinolite asbestos, and crocidolite asbestos are retained longer in the lower respiratory tract than chrysotile fibers of similar dimension.

- Individual risk factors, such as a person's history of tobacco use (smoking) and other pre-existing lung disease, etc.

Note: the combination of cigarette smoke and asbestos exposure significantly increase the chances of getting lung cancer. Clearly, those who have been exposed to asbestos should stop smoking (15).

Asbestos Health Effects and Toxicity

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

Malignant mesothelioma— cancer of the membranes (pleura) that encase the lungs and line 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 (6).

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 (6).

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) (6).

Toxicological Evaluation and Exposure Assessment

Evaluating the health effects of exposure to Libby asbestos requires extensive knowledge of toxicity data and exposure pathways. The toxicological information is currently limited and the exact level of health concern for different sizes and types of asbestos remains controversial.

There is limited information on past concentrations of Libby asbestos in the air of the former vermiculite processing facility and no available information on asbestos concentrations in exhaust emissions or outside air. Specific exposure pathway information at the St. Louis facility is also limited or unavailable. This makes it hard to estimate the levels of Libby asbestos that workers and neighborhood residents may have been exposed to. There are also uncertainties about the limited asbestos analyses from the past and significant uncertainties and conflicts in the methods presently used to analyze asbestos.

Because most exposures occurred long ago, not enough is known about how people may have been exposed to Libby asbestos from the plant or how often they may have been exposed. This information is necessary to estimate exposure doses. Also, there is insufficient information about how some vermiculite materials and waste materials were handled or disposed. All of this makes it difficult to determine past or potential current exposures.

Exposure Pathway Analysis

To determine exposure, DHSS evaluated the environmental and human components that lead to an exposure pathway. An exposure pathway describes how a person comes in contact with chemicals originating from a contamination source. ATSDR has determined that an exposure pathway consists of the following five elements:

1. A source of contamination,
2. A medium (air, soil, or water) 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 (inhalation or ingestion) or contacts the body, and
5. A receptor population.

A *completed exposure pathway* exists when the five elements of a pathway link the contaminant source to a receptor population. A *potential exposure pathway* indicates that exposure to a contaminant could have occurred in the past, could be presently occurring, 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 uncertain or missing. 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. The pathways have also been assigned a *public health hazard category* to describe the impact the exposure pathway is expected to have on public health. See Appendix E for definitions of the *public health hazards categories*.

Summary of Exposure Pathways at the Former Zonolite/W.R. Grace Facility – St. Louis

After reviewing information from Libby, Montana and the facilities that process vermiculite ore from Libby, a list of possible exposure pathways for vermiculite processing facilities was developed. All pathways have a common source—vermiculite from Libby contaminated with Libby asbestos—and a common route of exposure—inhalation. Although asbestos ingestion and dermal exposure pathways could exist, health risks from these pathways are minor compared to those resulting from inhalation and will not be evaluated.

The pathways considered for this site are listed in Table 1 below. The general pathways considered for each site as part of ATSDR's Phase 1 national effort to identify and evaluate potential asbestos exposures at 28 exfoliating sites that used Libby vermiculite, are shown in Appendix C, Table 1.

Table 1

Summary of Exposure Pathway Evaluations at the Former Zonolite/W.R. Grace Facility - St. Louis

Pathway Name	Exposure Scenario(s)	Timeframe	Pathway Status	Public Heath Hazard Determination
Occupational	Workers exposed to airborne Libby asbestos during handling and processing of contaminated vermiculite	Past (~late 1940s to 1988)	Completed	Public Health Hazard
	Current workers exposed to airborne Libby asbestos from residual contamination inside former processing buildings	Past/Present/Future (from 1990 on)	Potential	No Apparent Public Health Hazard
Household Contact	Household contacts exposed to airborne Libby asbestos brought home on workers' clothing	Past (~late 1940s to 1988)	Potential	Indeterminate Public Health Hazard
		Past/Present/Future (from 1990 on)	Eliminated	No Public Health Hazard
Community	Waste piles: Community members (particularly children) playing in or otherwise disturbing on-site piles of contaminated vermiculite or waste rock	Past	Potential	Indeterminate Public Health Hazard
		Present/Future	Eliminated	No Public Health Hazard
	On-site activity: Children playing in and around railroad cars used to haul contaminated vermiculite	Past	Potential	Indeterminate Public Health Hazard
		Present/Future	Eliminated	No Public Health Hazard
	On-site soils: Current on-site workers, contractors, or trespasser disturbing contaminated on-site soils (residual contamination, possible buried waste rock)	Past	Not Applicable	Not Applicable
		Present/Future	Potential	No Apparent Public Health Hazard
	Ambient air: Community members, nearby workers, and students/faculty at the Gratiot Grade School exposed to airborne fibers from plant emissions during handling and processing of contaminated vermiculite	Past (~late 1940s to 1988)	Potential	Indeterminate Public Health Hazard
		Past/Present/Future (From 1990 on)	Eliminated	No Public Health Hazard
	Residential outdoors: Community members using contaminated vermiculite or waste rock at home (for gardening, paving driveways, fill material) or deposition of fibers from facility emissions	Past	Potential	Indeterminate Public Health Hazard
		Present/Future	Potential	Indeterminate Public Health Hazard
	Residential indoors: Community members disturbing household dust containing Libby asbestos from plant emissions or waste rock brought home for personal use	Past	Potential	Indeterminate Public Health Hazard
		Present/Future	Potential	Indeterminate Public Health Hazard
	Consumer products: Community members, contractors, and repairmen disturbing consumer vermiculite products contaminated with Libby asbestos	Past	Potential	Indeterminate Public Health Hazard
		Present/Future	Potential	Indeterminate Public Health Hazard

Occupational (past ~late 1940s to 1988) – W.R. Grace records indicate that workers at the St. Louis exfoliating facility were exposed to airborne Libby asbestos. Limited available air sampling data between 1976 and 1986 showed time weighted averages (TWAs) ranging from 0.005 f/cc to 8.41 f/cc at the facility. The maximum value was reportedly taken when equipment was malfunctioning (unpublished information from US EPA's database of W.R. Grace documents). A number of the measured TWAs were above OSHA's current PEL TWA limit of 0.01 f/cc (although the levels were usually within the OSHA PEL TWA limit of 0.2 f/cc in effect at the time of sampling). The available records are from the time period after air pollution control equipment and other dust suppression measures had been added to exfoliating facilities (early 1970s). It is assumed that workers were exposed to even higher asbestos fiber levels in previous years. Also, intermittent use of personal protective equipment (masks) by the workers seems to have been the norm. On the basis of available information about worker exposures and because workers were most likely exposed to higher levels before the 1970s, this exposure pathway is considered *a public health hazard*.

W.R. Grace reportedly cleaned the St. Louis facility in 1990, after vermiculite processing ceased in approximately 1988. Little is known about activity at the facility between the time vermiculite processing ceased and the cleanup in 1990. During the dismantling of equipment and plant cleanup, workers could have been exposed to asbestos if proper personal protective equipment was not used. W.R. Grace collected indoor air samples along with an outdoor background air sample after the cleanup; laboratory analysis of these samples by PCM detected no visible fibers. It is not known if aggressive sampling was performed during the testing (e.g. if the air and dust surrounding the pump were disturbed to re-suspend any residual fibers during the sampling).

Occupational pathways (past/present/future from 1990 on) – Based upon available information from W.R. Grace, it is expected that since the facility wash down in 1990, workers inside the facility have not been exposed to hazardous levels of Libby asbestos. After wash down of the facility, confirmation air sampling was completed and no visible asbestos fibers were detected. These data are somewhat limited in that we do not know how the samples were collected and analyzed. Outside the facility, raw asbestos-contaminated vermiculite was found during the DHSS/ATSDR site visit in a small area of soil and weeds near the former silo area on the building's west side. The present manager stated that workers do not use this area and exposure to the contaminated soil is not expected to occur. A potential, but unlikely worker exposure pathway exists for this period, and it is considered a *no apparent public health hazard*.

Household contacts (past ~late 1940s to 1988) – In the past, household contacts of workers could have inhaled Libby asbestos from dirty work clothing or the hair of workers returning home after work. It is unknown how often this occurred or to what levels the household contacts may have been exposed. Available information indicates that the St. Louis facility was dusty and that workers were not provided work uniforms or required to shower before leaving work until the early 1980s. Until that time, workers may not have always observed precautions not to take dusty clothes home with them. These conditions would indicate a potential exposure pathway for household contacts of workers that could have occurred regularly in the past. Because conditions existing in the households at that time are unknown, this exposure pathway is considered an *indeterminate public health hazard*.

Household contacts (past/present/future from 1990 on) – Present occupational exposure to asbestos from the small area of residual waste in the soil next to the former silos is unlikely. The building was reportedly washed down before W.R. Grace sold the building, but the clearance sample results and methods may have been questionable. If asbestos fibers are still present in small quantities at the facility, it is expected that exposure would be intermittent and achieved through inhalation by the worker, but would not collect on their clothing. Consequently, the household contact pathway for this timeframe is considered eliminated and this exposure pathway is considered a *no public health hazard*.

Waste piles (past) – Available information indicates that waste rock was placed in dumpsters from the early 1970s and in later years bagged and wetted before being placed in dumpsters. The dumpsters were reportedly then hauled to a landfill and dumped. It is not known where the waste rock was disposed of prior to the 1970s, but waste piles reportedly were present and some may have been disposed of around the facility. Conversations with former workers and community members indicate that children played on these waste piles, which may have been an important past potential exposure pathway. Since we cannot determine the amount of exposure that may have occurred during the children's activity or other disturbances of the waste piles, this exposure pathway is considered an *indeterminate public health hazard*.

Waste piles (present/future) – No waste or vermiculite piles were found during the September 2002 site visit. A small amount of raw vermiculite was found in the soil near the unloading area. Because no waste piles now exist, the exposure pathway to the waste piles is eliminated and is considered a *no public health hazard*.

On-site activities (past) – The reported presence of children playing around the site and in railroad cars in the past represented a potential exposure pathway. Little is known about the amount of exposure to Libby asbestos that might have occurred and no judgment can be made on possible health effects. This exposure pathway is therefore considered an *indeterminate public health hazard*.

On-site activities (present/future) – The site is still accessible as it was in the past, but without the lure of the waste piles and railroad cars on which to play. Therefore, little activity other than occupational is expected on the site. Since contamination remains only in a small area of soil that has partial grass cover, this pathway has been eliminated and is considered a *no public health hazard*.

On-site soils (present/future) – Only the small area of contaminated soil with partial grass cover is known to be present on site and little or no exposure is expected to occur at this area. Samples taken by EPA from the railroad spur contained less than or equal to 1% asbestos. Reportedly, waste rock may have been disposed of on site, but is presently covered with asphalt or soil. Because exposure is expected only if major soil disturbances occur, this pathway is considered a *no apparent public health hazard*.

Ambient air (past ~late 1940s to 1988) – Community members, nearby workers, and the students and faculty of the Gratiot Grade School could have been exposed in the past to Libby asbestos released into the ambient air from fugitive dust or the furnace stack while the plant was operating. Children exposed to asbestos fibers would constitute a particularly sensitive population because of the length of time that the fibers would be in their lungs and the long latency period of asbestos-related diseases. According to wind rose data from the St. Louis International Airport for the late 1970s (Figure 4) the predominant wind direction was from the west-northwest toward other industrial areas and a residential area. The secondary wind direction would have been from the south toward another residential area. Ambient air data to predict actual exposure, including facility-specific emission levels, will probably never be known. No estimate of risk for this potential exposure pathway can be made and the pathway has been designated an *indeterminate public health hazard*.

Ambient air (past/present/future from 1990 on) – Since closure of the facility and cleanup in 1990, emissions into the ambient air have been eliminated and no exposure is expected. The air exposure pathway has been eliminated, and accordingly, the pathway is considered a *no public health hazard*.

Residential outdoor (past/present/future) – The exfoliating process and waste rock storage and handling were two sources of fugitive emissions from the facility. Air dispersion of asbestos fibers from plant emissions and the deposition of those fibers would have been greatest in the immediate vicinity of the facility. The concentration and deposition of asbestos fibers would decrease with increasing distance from the facility. The nearest residence is approximately one-quarter mile from the site. Off-site soil sampling by EPA at other exfoliating plants has not shown elevated levels of asbestos to be present in surrounding areas (16,17).

Prior to the 1970s, it is not known whether waste rock was used for fill material, paving, or added to gardens. The presence of actual waste rock in the community would be a greater concern than air deposited asbestos. Since the community is an urban area that was well established before the facility began operations, driveways and sidewalks are paved, and residences are located on small lots, it is not expected that much, if any, of the waste rock was used in the community. Given these unknowns and that these pathways cannot be completely eliminated, we assume that there is a potential exposure pathway if waste rock is present, and this exposure pathway has been designated as an *indeterminate public health hazard*.

Residential indoor (past) – In the past, residents could have inhaled Libby asbestos fibers from household dust, either from plant emissions that infiltrated into nearby homes or from contaminated dust from other sources. Because there is no information on facility emissions, ambient air levels in the community, or indoor air levels, it is impossible to determine the amount, if any, of indoor exposure. Because of these unknowns and the potential pathways that were present, it has been designated an *indeterminate public health hazard*.

Residential indoor (present/future) – The St. Louis facility no longer processes vermiculite and emissions from the facility are no longer present. Household cleaning over the years (especially wet cleaning methods) would likely have eliminated residual asbestos fibers from homes. If asbestos contaminated vermiculite insulation is present in the residence, a potential indoor exposure pathway could be completed if disturbance of the insulation occurred. This pathway, if present, constitutes a potential for exposure to Libby asbestos and has been designated an *indeterminate public health hazard*.

Consumer products (past/present/future) – People who purchased and used company products containing Libby asbestos may be exposed to asbestos fibers from using those products in and around their homes. Determining the public health implication of commercial or consumer use of company products (such as home insulation or gardening products) containing asbestos contaminated Libby vermiculite is beyond the scope of this assessment. However, studies have shown that disturbing or using these products can result in airborne asbestos fiber levels higher than occupational safety limits. A potential exposure pathway to these products has existed and continues to exist (18,19). Additional information concerning products that contain Libby vermiculite has been developed by EPA, NIOSH, and ATSDR and is available at www.epa.gov/asbestos/insulation.html.

Summary of Future Pathways – There are no known present completed exposure pathways at the former St. Louis facility. Although raw vermiculite with asbestos contamination is present in a small area of partially grass covered soil at the rear of the facility, it is not expected to be disturbed. Limited sampling at the site along the railroad spur detected asbestos equal to or less than 1%. Reportedly in the early years of operation, waste rock may have been used as fill around the site, but has since been covered with asphalt or soil. It is not likely that the industrial use of the site will change, but if changes are planned, additional sampling should be performed to determine if there are areas with elevated levels of asbestos that could pose a potential exposure pathway if disturbed. If waste rock were present in the community, then the disturbance of the waste rock or any asbestos contaminated consumer product releasing fibers would present a potential exposure pathway.

HEALTH OUTCOME DATA

The Missouri Department of Health and Senior Services (DHSS), in cooperation with ATSDR, conducted a health statistics review of the population living within the census tracts of 1036, 1039, 1041, 1042, 1045, 1121, and 1135. These census tracts surround the former St. Louis facility at 1705 Sulphur Avenue and represent the geographic area where exposure from the facility would most likely have occurred. According to the 1990 census the population of this area was 20,112. The data would not include workers at the Zonolite facility who lived outside the analyzed area, but focuses on the community surrounding the facility. Mortality based on death certificate data for the years 1979 to 1998 were compared to data from the National Center for Health Statistics. This period was chosen because (1) It covered the most recent years, (2) it corresponds to the approximate latency period for asbestos-related diseases, and (3) only one International Classification of Diseases (ICD-9) revision is used. DHSS cancer data were not used because ATSDR felt that there were not enough available years of data for a meaningful analysis.

Analyses of the 1979 to 1998 death certificate-based mortality data for the census tracts mentioned above did not indicate any abnormally high death rates from asbestos-related diseases. Six of the 12 diseases in the target area had standardized mortality ratios (SMRs) slightly greater than one, but these numbers were not statistically significant and were within the normal range of what would be expected. Considering the limitations of this type of data, the SMRs suggest that the occurrence of known asbestos-related disease (mesothelioma, asbestosis, and lung cancer) in the census tracts (areas most likely to be affected) are not significantly higher than expected when compared with the rest of the country. For a complete discussion of the *Health Statistics Review*, see Appendix D.

CHILD HEALTH CONSIDERATIONS

DHSS/ATSDR recognizes that infants and children might be more vulnerable than adults to exposures in communities faced with environmental contamination. Because children depend completely on adults for risk identification and management decisions, DHSS/ATSDR is committed to evaluating their special interests at the site.

The effects of asbestos on children are thought to be similar to those on adults. However, children could be especially vulnerable to asbestos exposure because of the following factors:

- Children are more likely to disturb fiber-laden soils or indoor dust while playing.
- Children are closer to the ground and thus more likely to breathe contaminated soils and dust.
- Children could be more at risk than people exposed later in life because of the long latency period between exposure and onset of asbestos-related respiratory disease.

Children most at risk are those who were household members of former workers and children who played around the site. Children attending the nearby school during the time the plant was in operation could also have been exposed. Historical exposures from past plant emissions, waste piles on site, and waste rock brought home and used in the yard are all indeterminate exposure pathways that cannot be evaluated due to lack of site-specific information. Because the facility is no longer processing vermiculite and only a small area of soil near the facility contains unprocessed vermiculite, children in the neighborhood are currently not likely to be exposed to Libby asbestos-contaminated vermiculite from the site.

CONCLUSIONS

Exposure to Libby asbestos from the former Zonolite/W.R. Grace facility at 1705 Sulphur Avenue could have occurred through a number of exposure pathways. The amount of fibers released into the air depends on the concentration of fibers in the source material and the nature of the disturbance. The risk of exposure to Libby asbestos fibers is proportional to the concentration of fibers in the air, the frequency and duration of exposure, and the number of pathways through which a person is exposed. Considering these points, the following conclusions and health hazards have been assigned. For a definition of the *health hazard categories*, see Appendix E.

1. Former workers at the Zonolite/W.R. Grace facility in St. Louis from approximately the late 1940s to 1988 were exposed to airborne levels of Libby asbestos above current occupational standards. Repeated exposure to asbestos as a result of working in and around the facility during active exfoliation of asbestos contaminated Libby vermiculite increases their risk of contracting an asbestos-related disease and posed a *past public health hazard*.

2. Household contacts of former workers could potentially have been exposed to Libby asbestos from contamination brought home on the clothing and hair of the workers from approximately the late 1940s to 1988. This past potential exposure of household contacts represents an *indeterminate public health hazard*.

3. The community around the facility and the students and faculty at the Gratiot Grade School may have been exposed to Libby asbestos fibers from approximately the late 1940s to 1988 when Libby vermiculite was exfoliated. Exposure may have occurred by disturbing or playing in asbestos-contaminated materials, from plant emissions, and waste rock brought home for personal use. Residents could also have been exposed when installing or disturbing asbestos-contaminated vermiculite insulation in their homes. Not enough information is available to determine how often or to what concentrations of airborne Libby asbestos they may have been or are being exposed to. As previously discussed, because of the long latency period of asbestos related diseases, those who were exposed as children could be at a higher risk of asbestos-related diseases. These exposure pathways represent an *indeterminate public health hazard*.

4. The facility no longer processes vermiculite from Libby; therefore, current and future exposure routes to Libby asbestos from air emissions have been eliminated for workers and the community. Limited data on past building cleanup and confirmation sampling indicate that current building occupants are unlikely to be exposed to hazardous levels of Libby asbestos. A small amount of unprocessed vermiculite and asbestos remains on site in partially grass-covered soil next to the former silo area; however, exposure is not

expected to occur. No waste piles of vermiculite or waste rock are present on site and any waste rock that was used for fill on site or in close proximity is covered with asphalt or soil. This asbestos contaminated waste rock would only be a health hazard if the waste rock were disturbed. For these reasons, the site has been designated a *no apparent public health hazard for the present and future*.

5. Use of waste rock in the community is not expected to be a major concern, but the possibility does exist that it was used in the community. Because it is not known if waste rock was used in the community or not, these pathways have been designated an *indeterminate public health hazard*.

RECOMMENDATIONS

1. DHSS/ATSDR will promote awareness of past asbestos exposures among former workers and their household contacts and recommends that individuals concerned about potential exposures consult their personal physician.

2. DHSS/ATSDR will promote awareness of potential asbestos exposures among nearby residents who lived in the area or attended the Gratiot Grade School during the period when the plant was operating and recommends that individuals concerned about potential exposures consult their personal physician.

3. As appropriate, DHSS/ATSDR will inform the site owner, the local health department, and the local planning/permit department that waste rock could be buried on the site so that the proper protective measures are taken to protect the community and on-site workers during excavation and major land disturbances.

4. DHSS/ATSDR will review additional site-specific information as it becomes available to further evaluate potential exposure pathways as applicable.

5. DHSS/ATSDR will provide information upon request to individuals concerned about asbestos-related health issues.

PUBLIC HEALTH ACTION PLAN

This Public Health Action Plan (PHAP) for the Zonolite/W.R. Grace facility in St. Louis, Missouri contains a description of actions to be taken by the Missouri Department of Health and Senior Services (DHSS), the Agency for Toxic Substances and Disease Registry (ATSDR), and other interested parties. The purpose of the PHAP is to ensure that this public health consultation not only identifies public health hazards, but provides an action plan to mitigate and prevent adverse human health effects resulting from past, present, and future exposures to hazardous substances at or near the site. Below is a list of public health actions to be implemented by DHSS, ATSDR, or other stakeholders at the site:

1. Actions completed:
   - ATSDR/DHSS conducted a site visit on September 18, 2002.
   - DHSS conducted limited investigations of the neighborhood for obvious signs of the use of waste rock, but none was detected.
   - DHSS discussed past conditions at the facility with former workers and community residents during its investigation of the site for this health consultation.
   - DHSS/ATSDR provided health information upon request to community members who were concerned about products containing vermiculite.
   - DHSS/ATSDR has addressed former employees and community health concerns and questions as they arose.
   - DHSS/ATSDR has provided educational information about asbestos to the current manager of the facility.
   - ATSDR and EPA have developed vermiculite attic insulation fact sheets that are available at www.epa.gov/asbestos/insulation.html.

2. Actions planned:
   - DHSS/ATSDR in cooperation with EPA will conduct a public availability session to answer questions, address concerns, provide appropriate health educational materials, gather information, and promote awareness of past asbestos exposure among former worker and the community.
   - DHSS/ATSDR will continue to provide health information upon request to individuals about asbestos-related health issues.
   - DHSS/ATSDR will continue to address community health concerns and questions as they arise and provide necessary community and health professional education.
   - DHSS will post the health consultation on its web site at http://www.dhss.mo.gov/
   - ATSDR will consolidate findings and recommendations from this health consultation and other priority sites nationwide that received Libby vermiculite.
   - ATSDR, in conjunction with state partners and other federal agencies, is investigating the feasibility of conducting additional worker and household contact follow up activities.
   - ATSDR will release reports summarizing health statistics review findings for selected sites for which data have been received.
   - DHSS/ATSDR will coordinate with the appropriate agencies to implement the recommendations in this public health consultation.

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CERTIFICATION

This Former Zonolite/W.R. Grace Facility – St. Louis Health Consultation was prepared by the Missouri Department of Health and Senior Services under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodologies and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

Technical Project Officer, CAT, SPAB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

Team Lead, CAT, SPAB, DHAC, ATSDR

Chief EICB, DHAC, ATSDR

APPENDICES

Appendix A

Figures:

1. Aerial Photograph of Former Zonolite Facility/W.R. Grace – St. Louis
2. Site Location and 1990 Demographic Statistics, Former Zonolite/W.R. Grace – St. Louis
3. Diagram of Former Zonolite/W.R. Grace Facility
4. Meteorological data from the St. Louis International Airport
5. Vermiculite
6. Waste Rock

Photographs 1 – 3: Former Zonolite/W.R. Grace Vermiculite Processing Facility

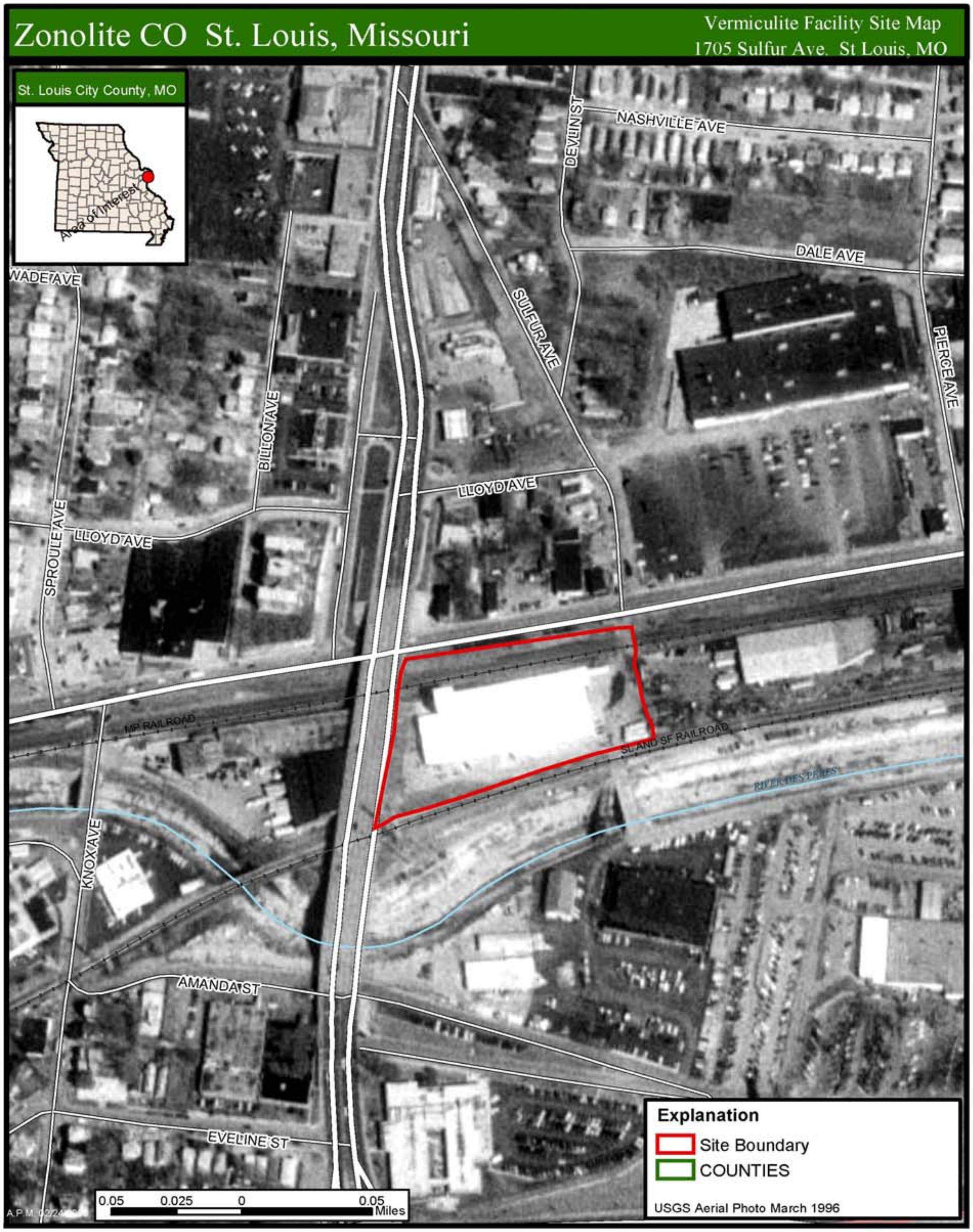

Zonolite CO St. Louis, Missouri
Vermiculite Facility Site Map
1705 Sulfur Ave. St Louis, MO
St. Louis City County, MO
Area of Interest
NASHVILLE AVE
DEVLIN ST
DALE AVE
WADE AVE
SULFUR AVE
PIERCE AVE
BILLON AVE
LLOYD AVE
LLOYD AVE
SPROULE AVE
MP RAILROAD
SL AND SF RAILROAD
RIVER DES PERES
KNOX AVE
AMANDA ST
EVELINE ST
0.05 0.025 0 0.05
Miles
Explanation
Site Boundary
COUNTIES
USGS Aerial Photo March 1996

Figure 2
Site Location and 1990 Demographic Statistics, Former Zonolite/W.R. Grace Facility – St. Louis

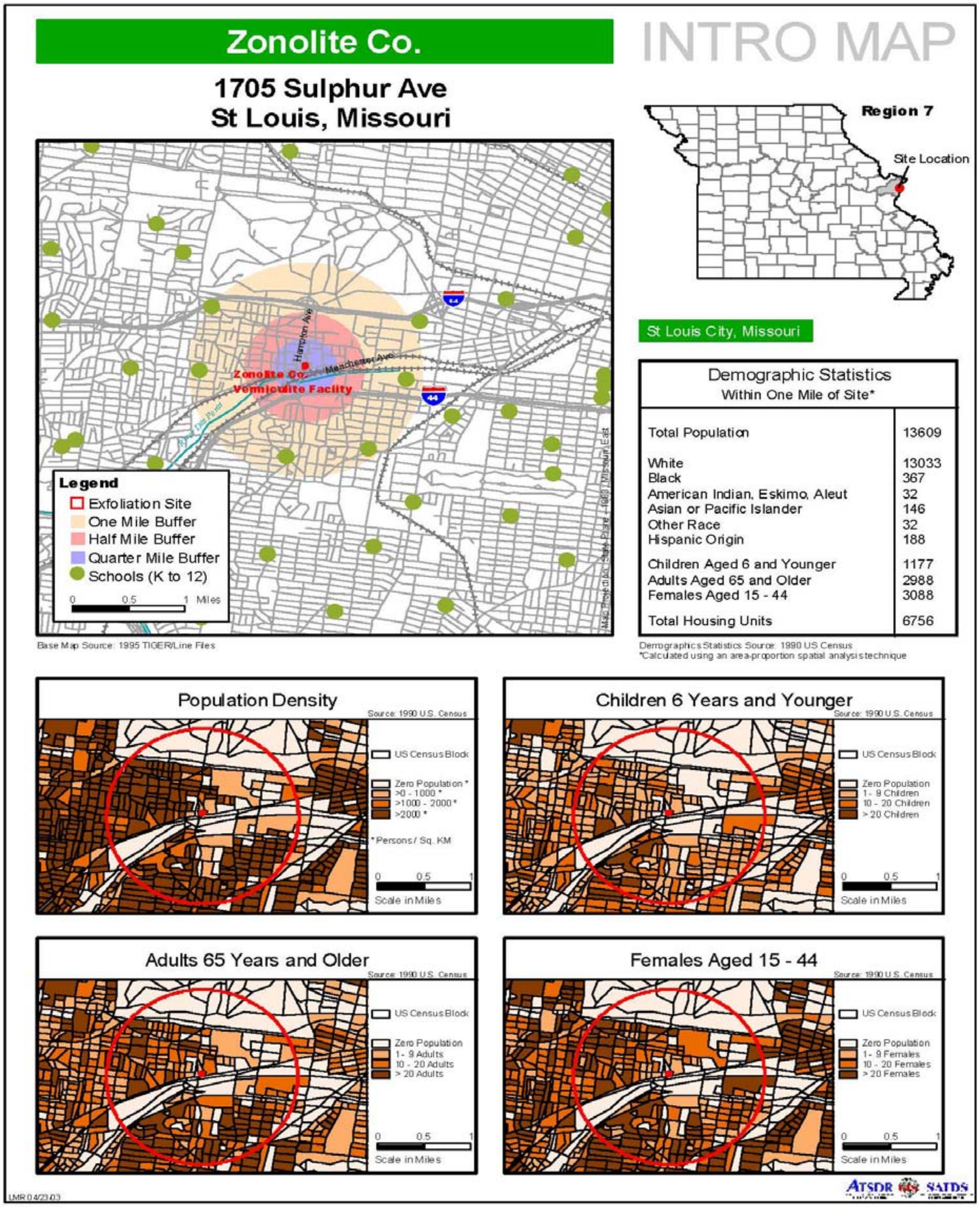
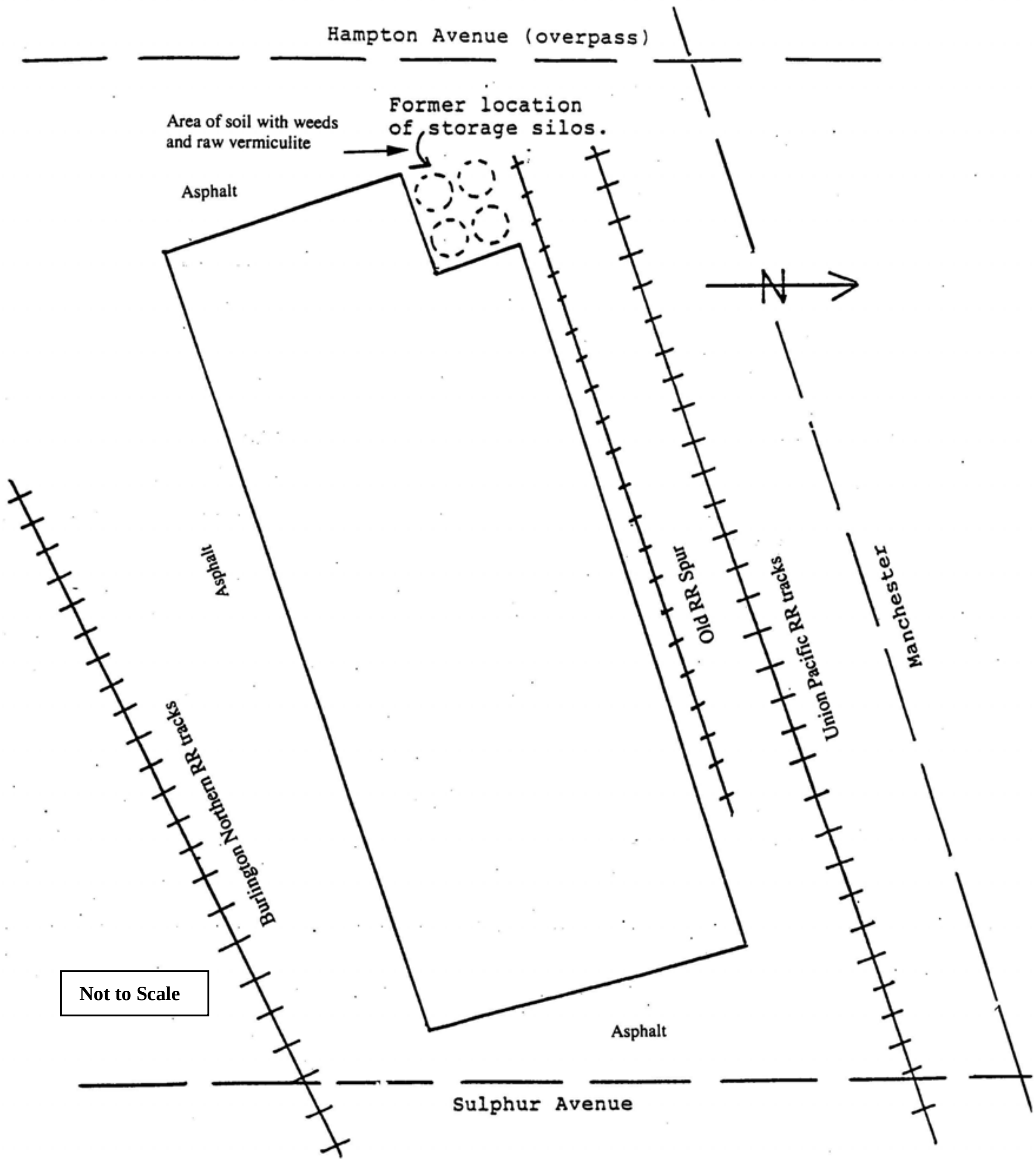


Figure 3
Diagram of Former Zonolite/W.R. Grace Facility – St. Louis, Missouri
1705 Sulphur Avenue



Source: Environmental Solutions Inc. Environmental Property Assessment at 1705 Sulphur Ave. 27 November 1990.

Figure 4
Meteorological data from the St. Louis International Airport

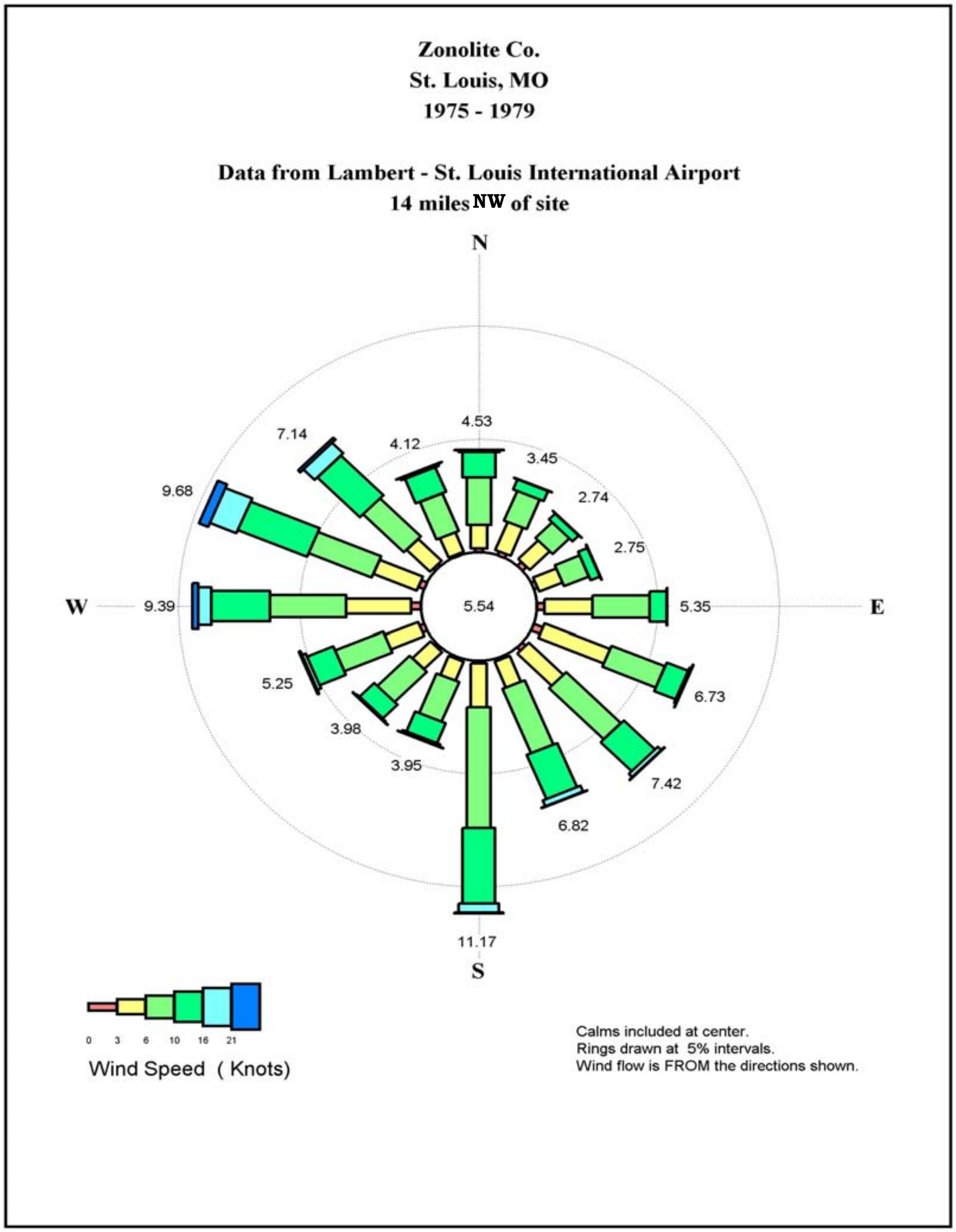


Figure 5. Vermiculite

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.

Photograph 1

North Side of Former Zonolite/W.R. Grace Facility – St. Louis, Missouri
September 18, 2002

Photograph 2

West side (rear) of Former Zonolite/W.R. Grace Facility – St. Louis, Missouri
Hampton Road Overpass on left with the Gratiot Grade School in background under overpass and grassy/weedy area with raw vermiculite material.
September 18, 2002

Photograph 3

Former Zonolite/W.R. Grace Facility – St. Louis, Missouri
Photograph from Gratiot Grade School front sidewalk looking southeast
at the Hampton Street Overpass and the Former Zonolite Facility
September 18, 2002

Appendix B

Asbestos Overview

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 stiff, brittle, and are rod or needle shaped. 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. The fibers are resistant to heat, fire, 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 that includes winchite, richterite, and tremolite as defined by Leake *et al*., 1997 (2,3); this characteristic material will be referred to as Libby amphibole asbestos (Libby asbestos). The raw vermiculite ore was estimated to contain up to 26% Libby asbestos as it was mined (4). 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% to 7% fibrous tremolite-actinolite by mass (4).

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 (length to width) ratio 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 that uses polarized light to compare refractive indices of minerals and that 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% to 1% asbestos.

Scanning electron microscopy (SEM) and, more commonly, transmission electron microscope (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 (EDX) methods, which give information on crystal structure and elemental composition, respectively, of the visualized fibers. SEM can be used in conjunction with EDX, but does not allow the measurement of electron diffraction patterns. A disadvantage of TEM 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 ($\mu g/m^3$)/(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 ($\mu g/m^3$)/(f/cc) (5). 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 (5). 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. Most cases of mesothelioma are attributable to asbestos exposure (1).

Lung cancer – Cancer of the lung tissue, also known as bronchogenic carcinoma. The exact mechanism relating asbestos exposure to lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk of developing lung cancer (1).

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) (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 protect the inhalation route of exposure should protect against dermal and oral exposures.

The scientific community generally accepts the associations between asbestos toxicity and fiber length and mineralogy. Fiber length may play an important role in clearance and fiber mineralogy may affect both biopersistence and surface chemistry.

In response to concerns about asbestos fiber toxicity from the World Trade Center disaster, ATSDR held an expert panel meeting to review fiber size and its role in fiber toxicity in December 2002 (6). The panel concluded that fiber length plays an important role in toxicity. Fibers with lengths <5 µm are essentially non-toxic with respect to mesothelioma or the promotion of lung cancer. 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 clarify this relationship.

Accordingly, 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 remains and builds up to high levels in lung tissue (7). 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 (7). However, OSHA continues to regulate chrysotile and amphibole asbestos as one substance, as both types increase the risk of disease (8). Currently, EPA's Integrated Risk Information System (IRIS) assessment of asbestos also treats mineralogy and fiber length as equally important.

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 suggest 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 (9).

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 clarified. For example, shorter fibers appear to deposit preferentially in the deep lung, but longer fibers may disproportionately increase the risk of mesothelioma (1,9). 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 being developed to assess the risks posed by varying types of asbestos are currently awaiting peer review (9).

Current Standards, Regulations, and Recommendations for Asbestos

In industrial applications, asbestos-containing materials are defined as any material with >1% bulk concentration of asbestos (10). It is important to note that 1% is not a health-based level, but rather 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 (11).

Friable asbestos (asbestos which is crumbly and can be broken down to suspendible fibers) is listed as a hazardous air pollutant in EPA's Toxic Release Inventory (12). 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 (8). 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 to more than1 f/cc as averaged over a sampling period of 30 minutes (8). 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. However, ATSDR does not support using the PEL for evaluating exposure for community members, because the PEL was developed as an occupational exposure for adult workers.

In response to the World Trade Center disaster in 2001 and an immediate concern about asbestos levels in buildings in the area, the Department of Health and Human Services, EPA, and the Department of Labor formed the Environmental Assessment Working Group. This group was made up of ATSDR, EPA, 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 reoccupation level of 0.01 f/cc after cleanup.

Continued monitoring was also recommended to limit long-term exposure at this level (13). In 2002, a multiagency task force headed by EPA 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 designed to be protective under long-term exposure scenarios, and it is based on risk-based criteria that include conservative exposure assumptions and the current EPA cancer slope factor. The 0.0009 f/cc benchmark for indoor air was formulated on the basis of chrysotile fibers and is therefore most appropriately applied to airborne chrysotile fibers (14).

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 workweek (15). The American Conference of Government Industrial Hygienists has also adopted a TWA of 0.1 f/cc as its threshold limit value (16).

EPA 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 (17). Many states use the same value as a human health water quality standard for surface water and groundwater.

Asbestos is a known human carcinogen. Historically, EPA's IRIS model calculated an inhalation unit risk for cancer (cancer slope factor) of 0.23 per f/cc of asbestos (5). This value estimates the 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 (5). Perhaps the most significant limitation is that the model does not consider mineralogy, fiber-size distribution, or other physical aspects of asbestos toxicity. EPA is in the process of updating their asbestos quantitative risk methodology given the limitations of the IRIS model currently used and the knowledge gained since this model was implemented in 1986.

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Appendix C

Potential Exposure Pathways for Vermiculite Processing Facilities
Table 1

Table 1

Potential. Exposure Pathways for Vermiculite Processing Facilities

Source for all pathways: Libby asbestos (asbestos-contaminated vermiculite from Libby, Montana)

Pathway Name	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 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 air from dirty clothing of workers 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	On site, at waste piles	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 soil (residual soil contamination, buried waste)	At areas of remaining contamination at the site 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 use (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

Appendix D:

Health Statistics Review for Populations
Close to the Zonolite Facility in St. Louis, MO.

Appendix D:

Health Statistics Review for Populations Close to the Zonolite Facility in St. Louis, MO*

Background

Through an analysis of mortality records, ATSDR and the Montana Department of Public Health and Human Services detected a statistically significant excess of asbestos-related disease (asbestosis) among residents of Libby, MT (1). Rates of asbestosis were 60 times higher than the national rates and this difference was highly unlikely due to natural fluctuations in the occurrence of this disease. This discovery led to several follow-up activities in Libby to address the health impacts on the community (2, 3). Another follow-up activity is a nation-wide effort to screen for a similar impact on the health of communities near facilities that processed or received vermiculite ore from the mine in Libby. As part of this activity, ATSDR is currently working with 25 state health departments (including the Missouri Department of Health and Senior Services (MDHSS)) to conduct health statistics reviews (HSR) on sites that may have received the asbestos-contaminated Libby ore. HSRs are statistical analyses of existing health outcome data (e.g., cancer registry data and/or death certificate data) that help provide information on whether people living in a particular community have gotten selected diseases more often than a comparison population (i.e., people living in the rest of the country). Finding an excess of asbestos-related diseases in a community through an HSR analysis would inform ATSDR and MDHSS to the possibility that workers and/or community members might have been exposed to Libby asbestos from the vermiculite ore. Participating state health departments are conducting HSRs for all of the communities in their state near vermiculite facilities, regardless of whether it is known if the community was exposed to Libby asbestos through the processing or handling of vermiculite ore. The methodology of the HSR used for the Zonolite Company site in St. Louis and other vermiculite sites across the US was developed by ATSDR (4).

Methods

Only mortality (i.e., death certificate) data were used for this analysis. The MDHSS cancer registry data were not used because ATSDR felt that there was not enough years of data available for a meaningful analysis. The target population/area for the mortality analysis consisted of people who died of potential asbestos-related diseases while residing within census tracts 1036, 1039, 1041, 1042, 1045, 1121, and 1135 (population 20,112 according to 1990 Census data). This combined census tract area was chosen because it contains all of the census tracts that surround the Zonolite Company site located at 1705 Sulphur Avenue in St Louis. Additionally, these census tracts were chosen because they represent the smallest geographic

* Provided to ATSDR Division of Health Assessment and Consultation by Kevin Horton, MSPH, ATSDR Division of Health Studies, February 2004.

areas surrounding the site that is electronically coded on MO death certificates. Furthermore, utilizing the city boundaries of large metropolitan areas such as St. Louis can be problematic because they have a greater chance of containing other potential asbestos sources (i.e., chemical and rubber manufacturing plants). Therefore, to filter out these other potential asbestos sources, the MDHSS chose to analyze the smallest geographic area possible.

The mortality analysis period chosen was from 1979-1998. This period was chosen because (1) it covered the most recent 20 years of mortality data available at the time the analysis began, (2) it corresponded to an approximate latency period in which initial exposure occurred and death would be expected, and (3) only one ICD revision is used. There were 12 disease groupings used for this mortality analysis (Table). Of the 12 groupings, the three of greatest interest to ATSDR were those having a known association with asbestos exposure. These three include asbestosis (ICD-9 501); malignant neoplasm of peritoneum, retroperitoneum, and pleura (ICD-9 158, 163, which includes mesothelioma); and malignant neoplasm of lung and bronchus (ICD-9 162.2-162.9). The other 9 disease groupings analyzed were reported in the literature as having weaker associations with asbestos exposure or were ones that were included to evaluate reporting/coding anomalies in the analysis areas.

Sex specific, age-standardized mortality ratios (SMRs) were calculated for asbestos-related deaths. An SMR is a measure of whether the number of people who died from selected diseases in the St. Louis target area is the same as, lower, or higher than the number of people we would expect to find if the occurrence of selected diseases in the St. Louis target area was the same as the occurrence of selected diseases in a comparison population. The comparison population used in this analysis was for the rest of the country. This comparison population was national death certificate data received from the National Center for Health Statistics (5). If the number of people who died from selected diseases in this St. Louis target area is the same as the number we would expect to find, the SMR will equal 1. If the number of citizens in this St. Louis target area who died from selected diseases is less than one would expect, the SMR will be between 0 and 1. If the number of citizens in this St. Louis target area who died from selected diseases is more than one would expect, the SMR will be greater than 1. Ninety-five percent confidence intervals (95% CIs) were calculated to assess statistical significance using Byar's approximation (6).

Results

For the time period 1979-1998, six of the 12 disease groupings in the St Louis target area had SMRs greater than one; however, these SMRs were not statistically significant and were within the normal range of what would be expected (Table 1). These six disease groupings included (1) malignant neoplasm of the respiratory system and intrathoracic organs, (2) malignant neoplasm of the lung and bronchus, (3) malignant neoplasm of the peritoneum, retroperitoneum, and pleura (includes mesothelioma),(4) malignant neoplasm without specification of site, (5) all malignant neoplasms, and (6) malignant neoplasm of the female breast.

Discussion and Limitations

The main goal of conducting these HSRs is to help determine if communities near facilities that received Libby vermiculite have higher than expected occurrences of asbestos-related diseases. The SMR analysis suggests that the occurrence of known asbestos-related diseases (i.e., mesothelioma, asbestosis, lung cancer) in the St. Louis target area do not appear to be significantly higher than expected compared to the rest of the country.

There are many limitations to using existing data sources to examine the relationship between environmental exposures and chronic diseases (a chronic disease is one that develops over a long period of time). Major limitations in this analysis include, but are not limited to: exposure misclassification, population migration, lack of control for confounding factors (i.e., smoking status), overstated numerators/underestimated denominators, large study areas, and small numbers of deaths. Most of these limitations would make it less likely (rather than more likely) that this type of analysis would identify a higher than expected occurrence of asbestos-related deaths among people who lived near the Zonolite Company site in St. Louis, MO during its years of operation.

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Table 1

Mortality data findings for residents who died from selected diseases in close proximity to the Zonolite Company target area in St. Louis, MO, 1979-1998 (includes census tracts 1036, 1039, 1041, 1042, 1045, 1121, and 1135 combined)

Selected disease	Past studies showing link to asbestos exposure?	Number of people who died	Expected number of deaths*	SMR†	95% CI‡ Range
Malignant neoplasm of selected digestive organs (ICD-9,§ 150–154, 159)	Weak link	172	196.7	0.9	0.7–1.0
Malignant neoplasm of respiratory system and intrathoracic organs (ICD-9, 161-165)	Yes	334	296.5	1.1	1.0–1.2
Malignant neoplasm of lung & bronchus¶ (ICD-9, 162.2–162.9)	Yes	319	286.6	1.1	1.0–1.2
Malignant neoplasm of peritoneum, retroperitoneum, and pleura (includes mesothelioma)¶ (ICD-9, 158, 163)	Yes	3	2.3	1.3	0.3–3.8
Malignant neoplasm without specification of site (ICD-9, 199)	No	81	73.0	1.1	0.9–1.4
Diseases of pulmonary circulation (ICD-9, 415-417)	No	23	28.8	0.8	0.5–1.2
Chronic obstructive pulmonary disease (ICD-9, 490–496)	No	181	211.1	0.9	0.7–1.0
Asbestosis¶ (ICD-9, 501)	Yes	0	0.6	0.0	N/A
Other diseases of respiratory system (ICD-9, 510–519)	No	22	38.6	0.6	0.4–0.9
All malignant neoplasms (ICD-9, 140–208)	No	1,154	1,112.3	1.0	1.0–1.1
Malignant neoplasm of female breast (ICD-9, 174)	No	116	93.1	1.2	1.0–1.5
Malignant neoplasm of prostate (ICD-9, 185)	No	65	66.9	1.0	0.7–1.2

* Calculated using mortality data received from the National Center for Health Statistics (unpublished data) [5].
† The Standardized Mortality Ratio (SMR) = the number of people who died divided by the expected number of deaths.
‡ The 95% confidence intervals (CIs) were calculated to assess statistical significance using Byar's approximation [6].
§ International Classification of Diseases, 9th Revision. Geneva: World Health Organization.
¶ Has known associations with asbestos exposure. The other disease groupings analyzed have weaker associations with asbestos exposure or were included to evaluate reporting/coding anomalies in the target area.

Appendix E

Exposure Pathways and Public Health Hazard Category Definitions

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Exposure pathways

An exposure pathway is the way in which an individual comes in 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 *potential* 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 uncertain or missing. 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 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 exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.