HEALTH CONSULTATION

SUPREME PERLITE

4600 N. SUTTLE ROAD

PORTLAND, MULTNOMAH COUNTY, OREGON

EPA FACILITY ID: ORO5102390

Prepared by the

Oregon Department of Human Services
Superfund Health Investigation & Education Program
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry
Division of Health Assessment & Consultation
Atlanta, Georgia

Foreword: ATSDR National Asbestos Exposure Review

Vermiculite, a mineral with many commercial and industrial uses, was mined in Libby, Montana, from the early 1920s until 1990. During those years, vermiculite from Libby was shipped to hundreds of locations throughout the United States. We now know that the vermiculite from Libby contained asbestos.

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

The evaluations focus on the processing sites and on human health effects that might be associated with possible past or current exposures. They do not consider commercial or consumer use of the products of these facilities.

The sites that processed Libby vermiculite will be evaluated by (1) identifying ways that people could have been exposed to asbestos in the past or 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 I: ATSDR has selected 28 sites for the first phase of reviews on the basis of the following criteria:

- The U.S. Environmental Protection Agency (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 ore from Libby mine. Exfoliation, a processing method in which ore is heated and “popped,” is expected to have released more asbestos than other processing methods.

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

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

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Purpose and Health Issues

Supreme Perlite is located at 4600 N. Suttle Road in an industrial area of north Portland near the Columbia River. From 1968 through 1974, Supreme Perlite received shipments of 639.28 tons (1,278,560 lbs) of Libby vermiculite (unpublished information from the Environmental Protection Agency's (EPA) database of W.R. Grace invoices) that were processed at the site and sold as attic insulation.

In response to scientific studies in the 1990s that indicated higher rates of asbestos-related health conditions in Libby, Montana [1, 2], EPA investigated a number of sites throughout the country where Libby vermiculite had been reportedly processed. As part of this investigation, EPA visited Supreme Perlite in April 2000 and collected soil and dust samples in and around the plant. Although Supreme Perlite processed a relatively low tonnage of Libby vermiculite, EPA identified the site for further investigation after sampling found asbestos contamination in an area where Libby vermiculite was unloaded from rail cars. Cleanup of the contaminated soil was completed in April 2001 [3]. EPA has no further action planned or required at this time for vermiculite cleanup at the Supreme Perlite site [4].

This health consultation evaluates the public health implications from past, present, and future exposure pathways to asbestos in Libby vermiculite exfoliated at the Supreme Perlite site. The Oregon Department of Human Services (ODHS) Superfund Health Investigation and Education program (SHINE) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

Site Description and History

The Supreme Perlite plant (21,634 square feet) is located on approximately 3 acres at the end of North Suttle Road (latitude 45.61626 N, longitude –122.71565 W) on a strip of industrial land between the Columbia River (approximately 750 feet to the north) and Smith Lake (approximately 750 feet to the south). The site location is shown in Figure 1. The area is zoned Heavy Industrial on land bordering Smith Lake, and is within Portland's NE Enterprise Zone. Bordering Supreme Perlite to the east (vacant until the 1980s) is a trucking company, and to the northeast is the Rhodia chemical plant (which was Stauffer Chemical from 1941-1987). Property to the west and north is undeveloped and heavily vegetated. Between Supreme Perlite and Smith Lake to the south are railroad tracks and a pedestrian trail (a former road constructed in the 1980s).

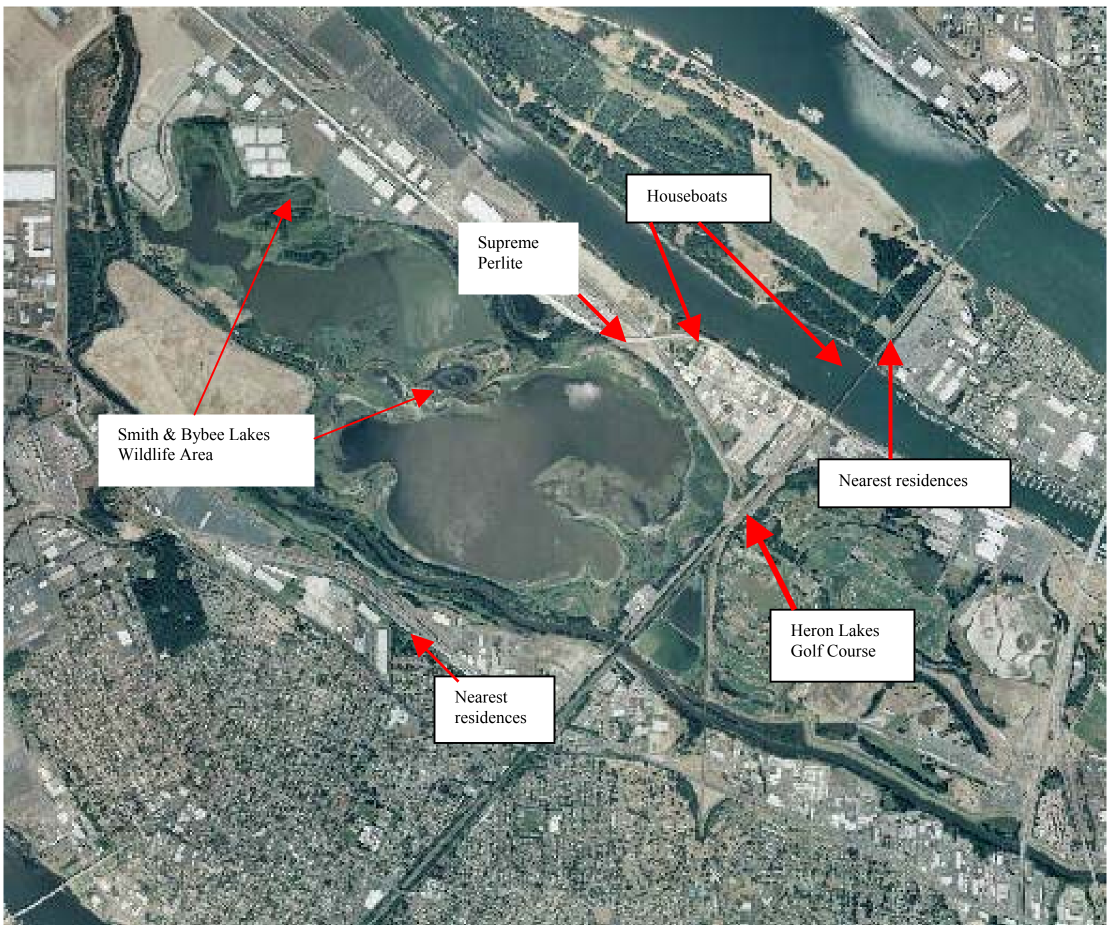
The nearest residences to Supreme Perlite are approximately 50 houseboats one-quarter mile to the northeast on the Columbia River. Aerial photographs from 1969 and 1972 (provided to SHINE by the Oregon Division of State Lands) show approximately 28 houseboats in that location. According to the 1990 census, there were 139 residents who lived within 1 mile of Supreme Perlite. The closest residential neighborhoods are approximately 1.25 miles northeast (on Hayden Island) and 1.5 miles to the south (see Figure 2). There are no schools within one mile of the property. Parks within one mile of the site include the Smith and Bybee Lake

Figure 1 – Demographics

Wildlife area, a 2,000-acre lake and wetland area to the south and west, and the northwest corner of the Heron Lakes Golf Course (opened to the public in 1971) located less than 3/4 miles to the southeast (see Figure 2).

Supreme Perlite, in operation since 1954, has primarily produced perlite, a material without asbestos that is similar to Libby vermiculite in its uses and processing requirements [5]. Like vermiculite, perlite is heated at high temperatures until water inside the material expands and the material exfoliates, or "pops." Supreme Perlite processed both vermiculite and perlite (in separate furnaces) until 1974 when the company decided to process only perlite. Until 1968, Supreme Perlite purchased vermiculite ore only from South Africa. From December 1968 to April 1974, Supreme Perlite also purchased twelve 55-ton railroad carloads of vermiculite ore from Libby, Montana (see Appendix B).

Figure 2 - Supreme Perlite vicinity



Supreme Perlite, managed by the current owner since the mid-1970s, was previously owned by his parents (now deceased) who purchased the plant in the early 1960s. According to the owner, there were 3 full-time employees (including the owner's father) and a few part-time factory employees (generally seasonal and varying in number according to product demand) who worked at the plant during the years Libby vermiculite was processed at the plant. According to the owner, one of the employees who worked at Supreme Perlite for 34 years, and was reportedly a heavy smoker, died of lung cancer two years after retiring in 1988. Vermiculite was processed in the western section of the plant, and perlite in the eastern section. The same employees worked in both sections of the plant, with processing of either vermiculite or perlite scheduled as orders were received, or in anticipation of seasonal needs (such as vermiculite attic insulation processed in the fall and winter). The only vermiculite product produced at Supreme Perlite was attic insulation, marketed as American Supreme Vermiculite. Supreme Perlite currently employs approximately 17 full- and part-time employees, including workers in both the factory and the office [6].

Vermiculite Processing

Vermiculite is a non-fibrous, platy weathered mica mineral type used in many commercial and consumer applications. Raw vermiculite ore is used in gypsum wallboard, cinder blocks, and many other products, and exfoliated vermiculite is used as loose fill insulation, as a fertilizer carrier, and as an aggregate for concrete. Exfoliated vermiculite is formed by heating the ore to 800^0 -1000^0 C [7], which explosively vaporizes the water contained within the mineral structure and causes the vermiculite particles to expand from 6 to as much as 30 times their original volume.

Over time, vermiculite from Libby was found to be contaminated with several types of asbestos fibers. Asbestos is a general name applied to a group of silicate minerals consisting of thin, separable fibers. Asbestos minerals fall into two classes – serpentine and amphibole. Serpentine asbestos has relatively long and flexible crystalline fibers; this class includes chrysotile, the predominant type of asbestos used commercially. Amphibole asbestos minerals are brittle and have a rod- or needle-like shape. Regulated amphibole minerals include amosite, tremolite actinolite, anthophyllite, and crocidolite [8]. Other amphibole minerals, however, including winchite, richterite, and others, can exhibit fibrous asbestiform properties. (See Appendix A for information on health effects from exposure to asbestos, analytical techniques, and regulations concerning asbestos.)

Asbestos fibers found in vermiculite from Libby include the amphibole asbestos varieties tremolite and actinolite and the related fibrous asbestiform minerals winchite, richterite, and ferro-edenite [7]. In this report, “Libby asbestos” (LA) is used to refer to the characteristic composition of asbestos contained in Libby vermiculite. The mined vermiculite ore was processed to remove unwanted materials and then sorted into various grades or sizes of vermiculite (from #0, or coarse, to #5, fine) that were then shipped by rail to sites across the nation for expansion (exfoliation) or use as a raw material in manufactured products. Some studies have suggested that the different ore grades may have had varying asbestos contents, with finer-sized grades having higher contamination [8, 10]. Additional studies suggest that the tremolite content ranged from 0.3% to 7% in the various grades of ore [11, 12].

Vermiculite was exfoliated at Supreme Perlite from 1954 until 1974, however vermiculite from Libby was exfoliated only from late 1968 until 1974. Prior to December of 1968, Supreme Perlite purchased vermiculite ore only from South Africa. (Several studies of vermiculite mined in South Africa, South Carolina, and Virginia reported that levels of amphibole asbestos were either not detectable or only present at much lower levels than those found in the Libby vermiculite [11, 12].) The Libby vermiculite shipped to Supreme Perlite was grade #1 and #3 (see Appendix B).

The following process information is primarily from interviews with the owner of Supreme Perlite, who began working at the facility in the early 1970s, and with a former employee who worked at the site from 1969 through 1978. Vermiculite ore was delivered to the facility in covered railcars on a former railroad spur on the south side of the facility. The vermiculite was emptied from the bottom of the railroad cars and was then transferred automatically by a 6-inch wide, 18 to 20-foot screw auger through two holes in the south wall of the plant to storage piles within the building. The vermiculite ore, described as 1/8 to 1/4-inch flakes, was moved from the piles by conveyor belt to a hopper. A forklift transferred the vermiculite in the hopper to a bucket elevator to another hopper where it was then dropped into the furnace (described as "home brew and not store-bought") for exfoliation. Exfoliated vermiculite was then moved by a bucket elevator to another hopper, and was then bagged for sale as insulation. (See Appendix C for a schematic of the process at this site.) Bags were stored inside the plant until they were transported from the plant by truck. Approximately 40 to 60 bags (4 cubic feet per bag) were processed per hour during fall and early winter months.

According to the owner and former employee, all exfoliated vermiculite (including any spillage during the process) was bagged for sale as attic insulation, and there was no waste (or "stoner rock") material remaining that would require storage or disposal. (Supreme Perlite had fill permits from 1988 to 1991 for on-site disposal of some perlite waste [13]. All perlite waste material now, according to the owner, is sold or is a component of various products produced on-site.)

There were several points during the process where workers were potentially exposed to dusty conditions, including unloading of the vermiculite from rail cars, use of the forklift and hopper to transfer the materials, and during the bagging of the exfoliated product. Emissions from the vermiculite furnace were vented horizontally from the front of the building approximately 15 feet above ground. During the years that Libby vermiculite was processed, the plant did not have emission devices (not required by law at the time) such as baghouses to capture dust from plant operations. (The plant has had an Air Contaminant Discharge Permit from the Oregon Department of Environmental Quality since 1978 [14].)

According to the owner, a vent above the perlite furnace at the highest section in the eastern area of the plant caused a thermal draft that pulled dust past the workers at the vermiculite furnace in the western section of the plant. During the winter months, strong east winds reversed the draft in the factory, and efforts were made whenever possible to schedule work during the times of day when winds were less strong.

During the years Libby vermiculite was processed at the plant, workers did not wear respirators or cotton disposable masks, and there were no changing areas, lockers, or shower facilities available. No reports of community complaints about dust from the facility were found, and no violations were reported by OR-OSHA (Oregon Occupational Safety and Health Administration) during the years vermiculite was processed [6]. While the plant now operates 120 hours per week, the plant operated Monday through Friday for 40 to 50 hours per week (depending on product demand) during the years that vermiculite was processed. The frequency and duration of former worker exposures to Libby asbestos would depend on their job assignment, facility operation schedule, and period of employment.

The vermiculite furnace was dismantled and removed from the property in the mid-1970s, and the vermiculite processing and storage area is now used as a general work area and for storage. The former railroad spur at the rear of the building (where ore was unloaded) is now covered with six inches of gravel and sand (to the top of the rail). A 12' by 18'concrete pad (installed in the 1980s) covers the soil from near the edge of the metal building to the northern rail of the former rail spur. Concrete blocks (2-ft high by 6-ft wide) now cover the narrow strip of soil between the building and the concrete pad.

Figure 3 Former Vermiculite Unloading Area (April 2000)

Site Visits

EPA staff visited the site on April 26, 2000. The owner conducted a walk-through of the site and identified areas formerly used for the off-loading, processing, and storage of vermiculite. Staff observed vermiculite "sparkles" in soil in a hole 6" below ground surface (dug by the owner prior to the site visit to assist EPA) between the tracks of the former rail spur at the rear of the building [15]. Seven samples were taken of dust and soil. Staff from EPA, ATSDR, and ODHS visited the site again in March 2001 [16]. ODHS/SHINE staff visited the site in June 2003 and in April 2004, and met with the owner who provided additional information on operating practices and land uses at neighboring properties during the years Libby vermiculite had been processed at the site. The site owner noted that before the construction of Marine Drive along the Columbia River in the mid-1990s, houseboats "seemed closer" as they were separated from the current industrial area by a former junkyard and vacant properties instead of the ten-foot-high sound wall constructed as part of the road project.

SHINE staff noted the following site details:

- A chain link fence encloses the site
- There are railroad tracks in front of and behind the plant.
- A graveled dirt roadway encircles the building. Open areas behind the plant provide truck access for loading and unloading.
- Bags of processed perlite were piled on the concrete pad and along the southwest perimeter, and there were piles of unprocessed materials stored at the southeast area of the property.

Soil Sampling

At the April 2000 site visit, EPA collected five soil samples and two dust samples [17]. Soil samples were taken along the building at the two areas where augers had transported vermiculite into the facility for processing, and from six inches below ground surface at the primary unloading site along the former rail spur. Dust samples were taken in the area near the former vermiculite furnace and in the area near the former hopper. (See Appendix D for sampling areas.)

EPA analyzed the soil and dust samples for asbestos content using both polarized light microscopy (PLM) and transmission electron microscopy (TEM). X–Ray diffraction PLM detected traces (<1%) of asbestos in 4 of the soil samples [17]. TEM analysis detected 1.2% tremolite-actinolite asbestos in one of the 4 soil samples (the sample at the former rail spur) and traces of asbestos in 3 of the remaining soil samples. The dust samples were non-detect for asbestos in both PLM and TEM. (See Table 1.)

Table 1 - Asbestos Sample Analytical Results - Samples collected April 26, 2000

Sample ID	SS1		SS2		SS3		SS4		SS5		Dust 1		Dust 2	
Percent	PLM	TEM	PLM	TEM	PLM	TEM	PLM	TEM	PLM	TEM	PLM	TEM	PLM	TEM
Total Asbestos	TR	1.2	TR	TR	TR	TR	TR	TR	ND	ND	ND	ND	ND	ND
Tremolite-Actinolite	TR	1.2	TR	TR	TR	TR	TR	TR	ND	ND	ND	ND	ND	ND

SS1 Soil 6 inches below ground surface south of concrete pad (former rail spur/unloading area)
SS2 Soil outside of building along back wall west of auger hole
SS3 Soil outside of building below west auger hole in wall (north of concrete pad)
SS4 Soil outside of building below east auger hole in wall (north of concrete pad)
SS5 White material inside building below west auger hole
Dust 1 Dust on rafters above area east of former furnace
Dust 2 Dust on rafters above area of former vermiculite hopper

TR Trace
ND No asbestos detected

IRS Environmental completed soil removal and remediation on April 18, 2001, [3] in the area where Soil Sample 1 had been collected. Vermiculite-containing soil was removed from an area of approximately two feet in depth and two feet in length at the former railroad spur at one of the vermiculite unloading areas. According to Ron Chaff, site foreman, (personal conversation in May 2004), soil with visible vermiculite was removed, along with a buffer of adjacent soil. Cleanup was based on visual observation of vermiculite in the soil. Certified Environmental Consulting conducted air sampling during the cleanup (detecting 0.03 and 0.0026 fibers per cubic centimeter (f/cc) - below the 0.1 f/cc OSHA PEL), however no confirmational air or soil sampling was conducted after cleanup was complete. There are no records of soil cleanup or sampling at the area along the rail spur at the second unloading area.

Climate

Portland, Oregon, has a relatively mild climate with an average temperature of 66^0 F in the summer and 38^0 F in the winter. Portland's average annual rainfall is 37 inches per year, with nearly 90% of rainfall occurring from October through May [18]. (See Appendix E for rainfall totals during the years 1968-1974 when Libby vermiculite was processed at the plant.) Precipitation is predominantly rain, with an average of only five days of measurable snow per year. Winds are primarily from the northwest, southeast, and the south (see Appendix F).

Discussion

Some of the vermiculite processed at Supreme Perlite originated from the mine in Libby, Montana, known to be contaminated with asbestos. Studies conducted in the Libby community indicate health impacts that are associated with asbestos exposure [19, 20]. 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. It is important to recognize, however, that the asbestos exposures documented in the Libby community are in many ways unique and will not collectively be present at other sites that processed or handled Libby vermiculite. The site investigation at Supreme Perlite is part of a national effort to identify and evaluate potential asbestos exposures that may be expected at these other sites. The Supreme Perlite site was selected for evaluation as part of the Phase 1 national effort the EPA listed it as a further action site.

Asbestos Health Effects and Toxicity

When asbestos fibers are breathed in, they may get trapped in the lungs. In general, health risks increase with longer exposure and greater amounts of asbestos fibers in the exposures. Short-term high-level or chronic low-level asbestos inhalation exposures have been associated with lung cancer, mesothelioma, asbestosis, and pleural disorders [8]. Breathing any type of asbestos increases the risk of the following health effects.

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

Malignant mesothelioma – Cancer of the membrane (pleura) that encases the lungs and lines the chest cavity. The great majority of mesothelioma cases are attributable to asbestos exposure [8]. An estimated 1,500 cases of mesothelioma per year occur in the United States (compared with an average of 130,000 cases of lung cancer per year). Latency periods for mesothelioma due to asbestos exposure are generally 20 to 30 years or more.

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 [21]. Latency periods are generally 10 to 30 years or more for lung cancer.

Noncancer effects – these include *asbestosis*, scarring and reduced lung function caused by asbestos fibers lodged in the lung; *pleural plaques*, localized or diffuse areas of thickening of the pleura (lining of the lung); *pleural thickening*, extensive thickening of the pleura which may restrict breathing; *pleural calcification*, calcium deposition on pleural areas thickened from chronic inflammation and scarring; and *pleural effusions*, fluid buildup in the pleural space between the lungs and the chest cavity [21]. Either heavy exposure for a short time [31] or lower exposure over a longer period may result in asbestosis [21]. Latency periods for the development of asbestos-related nonmalignant respiratory effects are usually 15-40 years from the time of initial exposure to asbestos.

There is not enough evidence to conclude whether inhalation of asbestos increases the risk of cancers at sites other than the lungs, pleura, and abdominal cavity [21].

Ingestion of asbestos causes little or no risk of noncancer effects. There is some evidence, however, 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 [21]. Skin nodules (corns) from handling asbestos-containing materials can also occur [1].

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

Exposure Assessment and Toxicological Evaluation

Evaluating the health effects of exposure to Libby asbestos requires extensive knowledge of both exposure pathways and toxicity data. The toxicological information currently available is limited and therefore the exact level of health concern for different sizes and types of asbestos remains controversial. Site-specific exposure pathway information is also limited or unavailable.

- There is no information on past concentrations of Libby asbestos in air in and around the plant. Also, significant uncertainties and conflicts in the methods used to analyze asbestos exist. This makes it hard to estimate the levels of Libby asbestos people may have been exposed to.
- There is not enough information known about how people came in contact with the Libby asbestos from the plant, and how often they were exposed, because no exposure data were collected and because most exposures happened so long ago. This information is necessary to estimate quantitative exposure doses.

Given these difficulties, the public health implications of past operations at this site are evaluated qualitatively. Current health implications are likewise evaluated qualitatively. The following sections describe the various types of evidence used to evaluate exposure pathways and reach conclusions about the Supreme Perlite site. Definitions for the hazard category terminology used to characterize the pathways are presented in Appendix G.

Exposure Pathway Analysis

An exposure pathway is how a person comes in contact with chemicals originating from a source of contamination. Every exposure pathway consists of the following five elements: 1) a *source* of contamination; 2) a *media* 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 pathway is considered complete if the pathway elements are (or were) present, but insufficient information is available to eliminate or exclude the pathway. A pathway may also be considered potential if it is currently missing one or more of the pathway elements, but the element(s) could easily be present at some point in time. An incomplete pathway is missing one or more of the pathway elements and it is likely that the elements were never present and 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 exposures.

After reviewing information from Libby, Montana, and from facilities that processed 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 ingestion and dermal exposure pathways for asbestos could exist, health risks from these pathways are minor in comparison to those resulting from inhalation exposure to asbestos and will not be evaluated.

The exposure pathways considered for each site in the Phase I evaluations are listed in Table 2. More detail on the pathways is included in Appendix H. Not every pathway will be identified as a significant source of exposure for a particular site. An evaluation of the pathways at Supreme Perlite is presented in the following paragraphs.

Occupational (past, present and future) –The past occupational pathway is a complete pathway and is considered the most significant exposure pathway at Supreme Perlite. Approximately 100 tons of LA per year were processed at the site over a six-year period (December 1968 through 1974) primarily during fall and winter months each year. The three full-time employees (and a few part-time and seasonal employees) who worked at Supreme Perlite during 1968-1974 were exposed to LA during the various stages of vermiculite processing, including the unloading of vermiculite from rail cars, during transfer of vermiculite by forklift from piles to the hopper to the furnace, and during the bagging of exfoliated material. According to the current plant owner, no pollution control equipment and dust suppression measures had been installed at the plant during this time period, and workers did not use respirators. No specific sampling data on levels of LA in the air in the plant are available for Supreme Perlite during years Libby vermiculite was exfoliated, however studies of workers at other sites indicate that LA vermiculite exfoliation workers have higher risk for developing asbestos-related disease and pleural changes [1]. While it is generally believed that non-malignant asbestos-related diseases are caused by long-term heavy exposures [21], short-term intense exposures to amphibole asbestos are also of concern. A recent case study analysis documented a fatal asbestosis case that resulted from exposure to LA-contaminated vermiculite during two consecutive summers of work at a vermiculite exfoliation facility in Southern California fifty years earlier [22].

EPA sampling in April 2000 found no LA in the dust samples taken inside the building. As vermiculite has not been processed at the plant since 1974, the vermiculite furnace was removed from the property in the mid-1970s, and dust sampling by EPA in 2000 found no LA, there are no known present or future exposure pathways for workers inside the facility. However, the methods for sampling and analysis of dust have improved since the initial sampling in 2000 and are now better able to quantify asbestos at levels of health concern. SHINE recommends that the site be revisited by the EPA for further limited dust sampling and analysis within the plant using more current methodology to ensure that the workers are not exposed to residual fibers.

Table 2 - Summary of Inhalation Pathways Considered for Supreme Perlite Site

Pathway Name	Exposure Scenario(s)	Past Pathway Status	Present Pathway Status	Future Pathway Status
Occupational	Former workers exposed to airborne Libby asbestos during handling and processing of contaminated vermiculite	Complete	Not applicable	Not applicable
	Current workers exposed to airborne Libby asbestos from residual contamination inside former processing buildings	Not applicable	Potential	Potential
Household Contact	Household contacts exposed to airborne Libby asbestos brought home on workers' clothing	Complete	Eliminated	Eliminated
Waste Piles	Community members (particularly children) playing in or otherwise disturbing onsite piles of contaminated vermiculite or waste rock	Incomplete	Incomplete	Incomplete
Onsite Soils	Current onsite workers, contractors, or community members disturbing contaminated onsite soils (residual contamination, buried waste)	Complete	Eliminated	Potential
Ambient Air	Community members or nearby workers exposed to airborne fibers from plant emissions during handling and processing of contaminated vermiculite	Potential	Eliminated	Eliminated
Residential Outdoor	Community members using contaminated vermiculite or waste material at home (for gardening, paving driveways, fill material)	Not applicable	Not applicable	Not applicable
Residential Indoor	Community members disturbing household dust containing Libby asbestos fibers from plant emissions or residential outdoor waste	Incomplete	Eliminated	Eliminated
Consumer Products	Community members, contractors, and repairmen disturbing consumer products containing contaminated vermiculite	Potential	Potential	Potential

Household contact (past, present, future) – Household contacts and family members may have been exposed to airborne LA brought home on clothing and hair of those who worked at the plant during 1968 through 1974. Vermiculite processing is known to be dusty, and at the Supreme Perlite site there was no filtering system in place, disposable suits were not worn, and workers did not shower or change clothes before going home. Although W.R. Grace proposed on-site laundering facilities for all their exfoliation facilities in 1984, the proposal was not implemented due to union disputes (EPA, unpublished data). Family or other household contacts may have come in contact with LA by direct contact with the worker, by laundering clothing, or by the re-suspension of dust during cleaning activities. Exposures to household contacts cannot be estimated without information concerning LA levels on worker clothing and behavior-specific factors (such as laundering practices and handling of clothing). Children of workers also visited the plant occasionally, and may have come into contact with LA in dust or air inside the plant. (One of the grown children of a former employee recalled visiting the site as a child, and referred to the plant as "the place that made me cough.") Asbestos-related disease in family members of asbestos industry workers is well documented [23, 24], including Libby, Montana, where household contacts of vermiculite workers were found to have an elevated prevalence of pleural abnormalities [20]. Past exposure to household contacts is considered a complete exposure pathway and a past public health hazard. Since vermiculite has not been processed at the site since 1974, the present and future household contact pathways are eliminated and are no longer a public health hazard.

Waste piles (past and present) –According to the site owner and a former employee, all exfoliated vermiculite (including swept up spillage) was bagged and sold as insulation and that no vermiculite waste materials were piled on-site or disposed of on-site. If any vermiculite waste has been disposed of on-site, the exposure pathway would be complete only during waste-disturbing activities (such as excavation), and none are known to be planned for the site at this time. Raw ore was stored in piles inside the building, and contact with the ore was reportedly limited to employees. Given the relatively small amount of Libby vermiculite processed at the site and the reported practices for disposal of perlite and vermiculite waste, it is unlikely that waste piles constitute a past, present or future pathway of exposure.

Onsite soils (past, present, future) – EPA sampling in April 2000 found 1.2% LA contamination in the soil at the railroad unloading area and traces of tremolite asbestos in three additional soil samples at the rear of the building in soil along the wall under holes where augers formerly carried vermiculite ore into the building. LA-contaminated soil was removed from the site up to two feet below ground surface along the rail of the former railroad spur at the primary ore unloading area in April 2001. In the mid-1980s, the rail spur was covered to the top of the rail with gravel and perlite fines, and a concrete pad covering most of the area between the rail spur and the building was constructed. A row of concrete blocks (8' by 5' in size) now covers a strip of soil along the building edge. Before soil was covered by concrete, gravel, and perlite fines, workers may have been exposed to LA during outdoor activities in that area of the site. It has been shown that disturbing soils with even trace amounts of LA can result in levels of respirable LA of concern [25, 26]. Onsite soil is considered an incomplete past exposure pathway. Exposures to LA-contaminated soil were of very short duration and were much less likely to lead to health effects than the high-level exposures that may have been experienced by workers during vermiculite processing at the plant.

No sampling has been conducted on the graveled soil at the secondary unloading site along the rail spur. As traces of LA were found in soil below both of the former auger entries, presence of LA along the rail at the second unloading area is likely. The soil along the rail is covered with several inches of gravel and perlite fines; a limited sampling of soil would help confirm that residual LA in this area is adequately covered. Soil along the former rail spur is an incomplete current pathway due to its inaccessibility and a potential future exposure pathway because of the possibility that any future action would disturb it.

Soil between the building and former rail spur may be contaminated with LA, however the concrete pad prevents exposure to workers and others accessing this area. Onsite soil in this area is an incomplete current pathway and should remain incomplete as long as the soil is covered with concrete. If site usage changes and the concrete pad is removed, the pathway would be a potential future exposure pathway, and additional sampling and remediation may be necessary. Concrete blocks recently placed on soil along the building limit exposure, however they are a less effective remedy than the concrete pad as they can be removed from the site.

Soil covered with gravel along a rail spur at the front of the plant has not been sampled for asbestos. There is no indication at this time that soil in this area is contaminated, however sampling for asbestos should be considered prior to any future excavation or major road or rail improvements.

The site is in a relatively remote location and site access is restricted by a chain-link fence, so it is unlikely that trespassers, children, or community members would have come in contact with contaminated soil prior to the covering of contaminated soil with concrete, gravel, and perlite fines in the mid-1980s.

As the contaminated areas at the rail spur at the rear of the plant have been cleaned up, and potentially contaminated soil is covered by concrete, there are no known present or future exposure pathways for workers or others who may access the site.

Ambient air (past, present and future) – Community members, workers in the Suttle Road industrial area, and (to a much lesser extent) golfers and visitors to the wildlife refuge could have been exposed in the past to LA fibers released into ambient air from fugitive dusts or the furnace vent while the plant was processing Libby vermiculite. No information is available, however, concerning emissions from the plant or of air sampling of employee work areas during the years Libby vermiculite was exfoliated at the site, so no estimate of risk from these exposures can be made. Even with emission data, it would be difficult to evaluate past exposures given the limited information on the population in the area at the time Libby vermiculite was processed at Supreme Perlite. An air dispersion model developed at a vermiculite processing plant in Minnesota suggested that areas very close (within one block) to an expansion plant could have had elevated fiber levels, but the levels were predicted to drop off rapidly as distance increased [27]. Site-specific emissions characteristics and meteorological conditions could affect results greatly; however, if a similar pattern existed at Supreme Perlite, it is unlikely that any of the people living near the plant (closest residence one-quarter mile away) were exposed to significant levels of LA fibers in ambient air.

Available wind rose data (from the Portland International Airport, 10 miles east of the site) indicate that winds during 1971-1975 were generally from the south, southeast and northwest (see Appendix F). Due to its location near the Columbia River, Supreme Perlite is also affected during the winter and summer months by strong east winds from the Columbia Gorge. Winds from the east and northwest would carry emissions away from houseboats northeast of Supreme Perlite. The processing of Libby vermiculite primarily during the rainy late fall and winter months may also have reduced exposure as individuals may have been more likely to have been indoors during the daytime hours when vermiculite was exfoliated.

The furnace vented horizontally about 15 feet above ground, which along with heavy rainfall may have caused emissions to concentrate in the immediate industrial area near the Supreme Perlite plant. Workers, particularly those who worked outdoors or in covered open structures at neighboring industrial sites to the east on Suttle Road (as well as workers at Supreme Perlite), may, as a result, have been exposed to high levels of LA. Due to the lack of data, however, no estimate of risks from this potential exposure can be made. Present and future exposures to Libby asbestos from air emissions were eliminated when the facility stopped processing Libby vermiculite in 1974.

Residential outdoor (past, present, future)- Based on available information, workers and community members face minimal (if any) risk of asbestos exposure from soils in their yards, either in the past or presently. The area immediately around the plant is industrial, and the closest residences are houseboats with no yards. Some vermiculite-processing facilities in the United States allowed or encouraged workers and the nearby community residents to take stoner rock, vermiculite, or other process materials for personal use [28]. According to the site owner and a former employee, all exfoliated material at Supreme Perlite was bagged for sale as insulation, and no waste materials remained to be removed from the site for personal use by workers, workers in neighboring industrial sites, or area residents for use in outdoor residential areas. The SHINE staff observed no visible signs of vermiculite stoner rock at the site, there were however piles of perlite product in different stages of processing.

Residential indoor (past, present, future) –There is no information on past levels of contamination in ambient air; however it is unlikely, due to weather conditions during the months when Libby vermiculite was primarily processed at the plant, that past ambient air emissions would have been high enough to infiltrate significantly into float homes about one-quarter mile (and more) to the northeast. According to wind records for the area, winds were generally from the south or northwest (see Appendix F). During late fall and winter months (when vermiculite was primarily processed at the site), winds were primarily from the east, which would have carried most emissions away from the houseboat locations (see Appendix E). Colder temperatures and heavy rain in these months make it also more likely that windows would have been kept closed. As waste material was reportedly not made available to workers and the nearby community, it is unlikely that vermiculite or waste material was used at homes of workers and within the community. Residual LA in homes is unlikely. Past exposures to residents inside their homes is considered an incomplete pathway. Current and future residential indoor exposure is considered to be an eliminated exposure pathway for community members.

Consumer products – People who purchased and used company products that contain Libby vermiculite may be exposed to asbestos fibers from using those products in and around their homes. At this time, determining the public health implication of commercial or consumer use of company products (such as home insulation or vermiculite gardening products) that contain Libby vermiculite is beyond the scope of this evaluation. However, studies have shown that disturbing or using these products can result in airborne fiber levels higher than occupational safety limits [25, 26].

Contaminated vermiculite used for home insulation and in gardening products mixed into soil could pose an inhalation hazard if it is disturbed. Exposure to asbestos in vermiculite insulation in an uninhabited attic or behind walls should be negligible. Exposure to asbestos in soil is less likely if the soil is covered by asphalt, concrete, or vegetation. Asbestos fibers do not break down in the environment, and asbestos in soil, may remain for decades [8].

Additional information on products that contain Libby vermiculite has been developed by EPA, ATSDR and NIOSH and is available to the public (see www.epa.gov/asbestos/insulation.html).

Health Effects Evaluation

When asbestos fibers are breathed in, they may get trapped in the lungs. In general, health risks increase with longer times of exposure and with greater amounts of asbestos fibers in the exposures. Short-term high-level or chronic low-level asbestos inhalation exposures have been associated with lung cancer, mesothelioma, asbestosis, and pleural disorders [8]. (See Appendix A for additional information on asbestos.)

Quantifying the risk of health effects from exposure to LA is difficult for several reasons. First is the lack of information on past concentrations of LA in air in and around the plant and appropriate exposure assumptions to make for activities that happened long ago. Even if this information was available, there are significant uncertainties and conflicts in the methods used to analyze asbestos, especially in the past. Finally, the exact level of health concern for different sizes and types of asbestos is controversial due to limitations in toxicological information currently available.

Health Outcome Data

Health outcome data can provide another level of analysis of the public health implications of a given exposure. Health outcome data can include mortality information (e.g., the number of people dying from a certain disease) or morbidity information (e.g., the number of people in an area getting a certain disease or illness). As a separate project, the ATSDR Division of Health Studies, in cooperation with state partners, is conducting an ongoing effort to gather health outcome data at selected former vermiculite facilities. The ODHS SHINE program is currently working with ATSDR to compile available mortality and morbidity information in the vicinity of the two facilities in Oregon that processed Libby vermiculite (Supreme Perlite and the former Vermiculite Northwest/W.R. Grace site in northeast Portland). As the population in the vicinity of Supreme Perlite is small, elevated health effects from exposure to vermiculite may be statistically difficult to determine. The health statistics review cannot prove a causal relationship between potential exposures and health outcomes, but it may indicate whether additional studies are needed. ATSDR will release annual reports summarizing health statistics review findings for sites where data has been received and evaluated.

Children's Health Considerations

SHINE and ATSDR recognize that infants and children might be more vulnerable to exposures than adults in communities faced with environmental contamination. Because children depend completely on adults for risk identification and management decisions, SHINE and ATSDR are committed to evaluating their special interests at the site. The effects of asbestos on children are thought to be similar to adults, however children could be especially vulnerable to asbestos exposures due to 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 or 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.

The most at-risk children (who are now adults) are those who were household contacts of workers during the years 1968 to 1974 when the plant was exfoliating Libby vermiculite. In addition to being exposed to LA brought home on workers clothing, children reportedly visited parents occasionally at the factory and may have been exposed to LA in air or dust inside the plant. Vermiculite ore was stored in piles inside the plant. These ore storage piles were not accessible to area children, and there is no indication that children of employees were in contact with these storage piles. There were reportedly no waste piles children could have played on during the years vermiculite was processed at the site. Due to its location on the site, fencing, and the remote location of Supreme Perlite, it is highly unlikely that children were exposed to any contaminated soil at the site. There are no known current exposure pathways to vermiculite processed at Supreme Perlite that could pose a public health hazard for children.

Conclusions

Based on the data reviewed for Supreme Perlite, SHINE concludes the following:

- Workers employed at Supreme Perlite during 1968-1974 were exposed to elevated levels of Libby asbestos as a result of working in and around the facility during unloading and exfoliation of Libby vermiculite, and these exposures were a *past public health hazard*. Exposure to asbestos does not necessarily mean an individual will get sick. The frequency, duration, and intensity of the exposure, along with personal risk factors such as smoking, history of lung disease, and genetic susceptibility determine the actual risk for an individual.

- Current workers at facilities that processed LA may be exposed to residual asbestos fibers in indoor dust. EPA sampling in April 2000 found no LA in the dust samples, however, the methods for sampling and analysis of dust have improved and are now better able to quantify asbestos at levels of health concern. Current and future exposure to contaminated dust at the site is considered an *indeterminate public health hazard* for workers.
- Household contacts of former workers were also likely to have been exposed to Libby asbestos brought home on clothing and hair of workers. Although exposure data are not available for household contacts, their exposures are inferred from documented former worker exposures and facility conditions that did not prevent contaminants being brought into the workers' homes. Exposure to household contacts in the past represents a *public health hazard*.
- Contaminated soil was removed from the primary rail unloading area up to two feet below ground level in April 2001. Most of the soil between the building and former rail spur is covered by a concrete pad and by large concrete blocks. Prior to cleanup and covering of potentially contaminated soil, workers may have been exposed to asbestos, however the exposure would have been much less than for the vermiculite processing workers. Contaminated soil at the site was a *past indeterminate public health hazard* for workers. Future exposures to Libby asbestos in soil under the concrete pad and along the edge of the building are unlikely unless the concrete pad and/or concrete blocks are removed so that soil in these areas are disturbed.
- Several inches of gravel and perlite fines cover soil along the former rail spur vermiculite unloading area. Soil in a hole at the primary ore unloading area was sampled and contaminated soil at this unloading area was removed, however no samples were taken of surface soil in this area after cleanup was completed, and no surface soil samples were taken at the secondary ore unloading area. Any remaining LA-contaminated soil may be adequately covered, however since no surface soil sampling was completed along the rail spur, soil in this area of the plant is considered an *indeterminate public health hazard*.
- There is not enough information to determine the extent of past exposure to residents of nearby houseboats and workers in neighboring industrial sites from air emissions from the plant. Past exposure from ambient air is considered *no apparent public health hazard* for residents of houseboats and an *indeterminate public health hazard* for workers at nearby industrial sites. As vermiculite is no longer processed at the site, pathways for current or future community exposure to airborne emissions have been eliminated and pose *no public health hazard*.
- According to the owner and former employee, there were no waste products or waste piles from vermiculite processing, and workers did not remove vermiculite materials from the site for personal use. Vermiculite ore was stored in piles inside the building and was not accessible to the community, and there is no indication that children of workers were in contact with the ore piles. Exposure to waste products from the site is unlikely and considered *no apparent past, present, or future public health hazard*.

Recommendations

- Promote awareness of past asbestos exposures among former workers and members of their households.
- Conduct limited dust sampling and analysis within the plant using more current methodology to ensure that the workers are not exposed to residual fibers.

- Soil in the area behind the building now covered with the concrete pad and concrete blocks should remain covered. Moreover, the condition of the concrete pad and blocks should be checked to reduce potential exposure. Future developers or site occupants should be notified that soil under the concrete pad and along the rear of the building adjacent to the concrete pad may be contaminated with Libby asbestos and that prior to disturbing these soils appropriate engineering controls should be implemented to minimize exposure and protect public health.
- Conduct limited sampling of soil at the primary and secondary unloading areas along the former rail spur at the rear of the building. Until sampling and cleanup (if indicated) are completed, actions (such as restricting soil disturbance, covering the area, or keeping the area wet) should be taken to reduce potential exposure.
- Review site-specific information as it becomes available and utilize any new information to evaluate indeterminate exposure pathways as applicable.
- Provide educational materials concerning asbestos-related exposures and health issues to exposed individuals and concerned community members.
- Work with the correct state or federal authority and the City of Portland Office of Planning and Development to arrange permit restrictions to ensure adequate controls are in place to protect workers from asbestos exposure during excavation or disturbance of onsite soils.
- Determine if it is appropriate to work with an environmental state or federal authority to file a public notice to be attached to the records for this property.

Public Health Action Plan

The Public Health Action Plan for Supreme Perlite contains a description of actions that have been or will be taken by ATSDR, SHINE, and/or other government agencies at the site. The purpose of the Public Health Action Plan is to ensure that, in addition to identifying public health hazards, a plan of action is provided that is designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of ATSDR to follow up on this plan to ensure its implementation.

Actions Completed

- EPA conducted site visits and collected environmental samples at the site in April 2000.
- ATSDR, EPA, and ODHS staff conducted a site visit in March 2001. ODHS/SHINE staff conducted site visits in June 2003 and April 2004.
- Cleanup of contaminated soil at the primary unloading area along the rail spur was completed by the property owner through a private consultant under the oversight of EPA in April 2001.
- Vermiculite attic insulation fact sheets have been developed by ATSDR, NIOSH, and EPA and are available at www.epa.gov/asbestos/insulation.html. EPA has begun implementing a consumer awareness campaign for vermiculite attic insulation.
- SHINE created a fact sheet with site-specific information on the Supreme Perlite facility. (See Appendix I).

Actions Ongoing

- ATSDR will combine the findings from this health consultation with findings from other sites nationwide that received Libby vermiculite to create a report outlining overall conclusions and strategies for addressing public health implications.
- SHINE and ATSDR staff are conducting a health statistics review of the area in the immediate vicinity of the Supreme Perlite site. Health statistics reviews are statistical analyses of existing health outcome data (e.g., cancer registry data and death certificate data) on populations near selected sites of concern to determine if an excess of disease(s) has

occurred. SHINE is reviewing available electronic data, which includes mortality data and cancer incidence data from 1979 through 1998.

Actions Planned

- ATSDR, in cooperation with SHINE and other state partners and federal agencies, is researching and determining the feasibility of conducting worker and household contact follow-up activities.
- SHINE will endeavor to identify and contact employees to provide information and to encourage them and their household members to consult an occupational medicine physician for a health evaluation if they believe they were exposed to Libby asbestos.
- SHINE will work to provide educational materials and site-specific information upon request to former workers, their families and other household members; and those who lived or worked near the Supreme Perlite site who may have concerns or questions about vermiculite exposure.
- SHINE will work with a state or federal authority and the City of Portland Office of Planning and Development to arrange permit restrictions to ensure adequate controls are in place to protect workers from asbestos exposure during excavation or disturbance of onsite soils.
- SHINE will determine if it is appropriate to work with an environmental state or federal authority to file a public notice to be attached to the records for this property.

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Appendix A – Asbestos Overview

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

Asbestos fibers do not have any detectable odor or taste. They do not dissolve in water or evaporate and are resistant to heat, fire, and chemical and biological degradation.

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

The following sections provide an overview of several concepts relevant to the evaluation of asbestos exposure, including analytical techniques, toxicity and health effects, and the current regulations concerning asbestos in the environment. A more detailed discussion of these topics will also be provided in ATSDR's upcoming Summary Report for the national review of vermiculite sites.

Methods for Measuring Asbestos Content

There are a number of different analytical methods 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 an aspect ratio (length-to-width) greater than 3:1. This is the standard method by which regulatory limits were developed. Disadvantages of this method include the inability to detect fibers thinner than 0.2 to 0.3 µm in diameter (and shorter than 5 µm) and the inability to distinguish between asbestos and nonasbestos fibers [1].

Asbestos content in soil and bulk material samples is commonly determined using polarized light microscopy (PLM), a method which uses polarized light to compare refractive indices of minerals and can distinguish between asbestos and nonasbestos fibers and between different types of asbestos. The PLM method is also limited by resolution; fibers finer than about 1 µm in diameter cannot be identified by PLM. Detection limits for PLM methods are typically 1% asbestos by volume.

Scanning electron microscopy (SEM) and, more commonly, transmission electron microscopy (TEM) are more sensitive methods and can detect smaller fibers than light microscopic techniques. One disadvantage of electron microscopic methods is that it is difficult to determine asbestos concentration in soils and other bulk materials [1].

Historically, the majority of epidemiological studies performed on asbestos exposure used phase contract microscopy (PCM) to determine fiber levels in the air (f/cc). Advances in technology (e.g., transmission electron microscopy, or TEM) allows measurement of fibers that are many times smaller than those that would have been detected by PCM and thus typically results in counts much higher than would be seen had PCM been used. Therefore, for risk assessment purposes, TEM data needs to be converted to an equivalent PCM value: referred to as PCM equivalents (PCMe). Two ways to make this conversion are : 1) Count (or bin) fibers with sizes equal to those that would be counted with PCM (diameter >0.4µm and length > 5µm) or, 2) make simultaneous measurements of TEM counts and PCM counts and compute a conversion factor. It should be noted that even under the best of circumstances, PCMe conversions can be up to 22-53% in error (U.S.EPA, 1986).

In limited situations PCM fiber levels can be higher than TEM levels. Since PCM cannot determine fiber types, environments that may have high non-asbestos fiber loads will show higher PCM fiber counts than TEM, which distinguishes asbestos fibers from non-asbestos fibers. In general, it has been assumed that the epidemiological literature is based on fiber environments that were predominantly asbestos, in which PCM did not significantly overestimate fiber loads. However, this limitation may be important in environments that contain non-asbestos fibers and are being measured by PCM.

EPA is currently working with several contract laboratories and other organizations to develop, refine, and test a number of methods for screening bulk soil samples.

Asbestos Health Effects and Toxicity

When asbestos fibers are breathed in, they may get trapped in the lungs. In general, health risks increase with longer exposure and greater amounts of asbestos fibers in the exposures. Although short-term high-level or chronic low-level asbestos inhalation exposures have been associated with lung cancer, mesothelioma, and pleural disorders [3]. 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. The great majority of mesothelioma cases are attributable to asbestos exposure [1]. An estimated 1,500 cases of mesothelioma per year occur in the United States (compared with an average of 130,000 cases of lung cancer per year). Latency periods for mesothelioma due to asbestos exposure are generally 20 to 30 years or more.

Lung cancer – Cancer of the lung tissue, also known as bronchogenic carcinoma. The exact mechanism relating asbestos exposure with lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk of developing lung cancer [1]. Latency periods are generally 10 to 30 years or more for lung cancer.

Noncancer effects – these include *asbestosis*, scarring and reduced lung function caused by asbestos fibers lodged in the lung; *pleural plaques*, localized or diffuse areas of thickening of the pleura (lining of the lung); *pleural thickening*, extensive thickening of the pleura which may restrict breathing; *pleural calcification*, calcium deposition on pleural areas thickened from chronic inflammation and scarring; and *pleural effusions*, fluid buildup in the pleural space between the lungs and the chest cavity [1]. Either heavy exposure for a short time [32] or lower exposure over a longer period may result in asbestosis [1]. Latency periods for the development of asbestos-related nonmalignant respiratory effects are usually 15-40 years from the time of initial exposure to asbestos.

There is not enough evidence to conclude 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 noncancer effects. There is some evidence, however, 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]. Skin nodules (corns) from handling asbestos-containing materials can also occur [3].

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

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

ATSDR, responding to concerns about asbestos fiber toxicity from the World Trade Center Disaster, held an expert panel meeting to review fiber size and its role in fiber toxicity in December 2002 [4]. The panel concluded that fiber length plays an important role in toxicity. Fibers with lengths less than 5μm (1μm is about 1/25,000 of an inch) are essentially non-toxic when considering a role in mesothelioma or lung cancer promotion. However, fibers less than 5 μm in length may play a role in asbestosis when exposure duration is long and fiber concentrations are high. More information is needed to definitively make this conclusion.

In accordance with these concepts, it has been suggested that amphibole asbestos is more toxic than chrysotile asbestos, mainly due to physical characteristics that allow chrysotile to be broken down and cleared from the lung, whereas amphibole is not removed and builds up to high levels in lung tissue [5]. Some researchers believe the resulting increased duration of exposure to amphibole asbestos significantly increases the risk of mesothelioma and, to a lesser extent, asbestosis and lung cancer [5]. OSHA, however, continues to regulate chrysotile and amphibole asbestos as one substance, as both types increase the risk of disease [6]. EPA's Integrated Risk Information System (IRIS) assessment of asbestos also treats mineralogy (and fiber length) as equipotent [7].

Evidence suggesting that the different types of asbestos fibers vary in carcinogenic potency and site specificity is limited by the lack of information on fiber exposure by mineral type. Other data indicate that differences in fiber size distribution and other process differences can contribute at least as much to the observed variation in risk as does the fiber type itself [5].

Counting fibers using the regulatory definitions (see below) does not adequately describe risk of health effects, as fiber size, shape, and composition contribute collectively to risks in ways that are still being elucidated. For example, shorter fibers appear to preferentially deposit in the deep lung, but longer fibers might disproportionately increase the risk of mesothelioma [1,8]. 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 do not contribute significantly to risk. Methods are being developed to assess the risks posed by varying types of asbestos and are currently awaiting peer review [8].

Current Standards, Regulations, and Recommendations for Asbestos

In industrial applications, asbestos-containing materials are defined as any material with greater than 1% bulk concentration of asbestos, where asbestos includes only the 5 regulated asbestiform minerals (i.e., fibrous tremolite, actinolite, anthophyllite, crocidolite, and amosite) [9]. It is important to note that 1% is not a health-based level, but instead represents the practical detection limit in the 1970s when OSHA regulations were created. Studies have shown that disturbing soils containing less than 1% amphibole asbestos can suspend fibers at levels of health concern [9].

Friable asbestos (asbestos which is crumbly and can be broken down to suspendable fibers) is listed as a Hazardous Air Pollutant on EPA's Toxic Release Inventory [11]. This requires companies that release friable asbestos at concentrations greater than 0.1% to report the release under Section 313 of the Emergency Planning and Community Right-to Know Act.

Low levels of asbestos can be detected in almost any air sample. In rural areas, for example, there are typically 10 fibers in a cubic meter (fibers/m3) of outdoor air (or 0.00001 fibers per cubic centimeter (cc). (A cubic meter is about the amount of air someone breathes in 1 hour.) Health professionals often report the number of fibers in cubic centimeters (f/cc); 10 fibers per cubic meter is the equivalent of 0.00001 f/cc. Typical levels found in cities are about 10 times higher. Close to an asbestos mine or factory, levels may reach 10,000 fibers/m3 (or 0.01 f/cc) or higher. Levels could also be above average near a building that contains asbestos products and is being torn down or renovated or near a waste site where asbestos is not properly covered up or stored to protect it from wind erosion [1].

OSHA has set a permissible exposure limit (PEL) of 0.1 f/cc for asbestos fibers longer than 5 µm and with an aspect ratio (length-to-width) greater than 3:1, as determined by PCM [12]. This value represents a time-weighted average (TWA) exposure level based on 8 hours a day for a 40-hour workweek. In addition, OSHA has defined an excursion limit in which no worker should be exposed in excess of 1 f/cc as averaged over a sampling period of 30 minutes [12]. Historically, the OSHA PEL has steadily decreased from an initial standard of 12 f/cc established in 1971. The PEL levels prior to 1983 were determined based upon empirical worker health observations, while the levels set from 1983 forward employed some form of quantitative risk assessment. ATSDR has used the current OSHA PEL of 0.1 f/cc as a reference point for evaluating asbestos inhalation exposure for past workers. ATSDR does not, however, support using the PEL for evaluating community member exposure, as the PEL is based on an unacceptable risk level.

In response to the WTC disaster in 2001 and an immediate concern about asbestos levels in homes in the area, ATSDR formed the Environmental Assessment Workgroup. This workgroup was made up of ATSDR, US Environmental Protection Agency, National Institute of Occupational Safety and Health, CDC National Center for Environmental Health, Occupational Safety and Health Administration, New York City Department of Health and Mental Hygiene, and the New York State Department of Health. The workgroup set a re-occupation level of 0.01 f/cc if after clean-up continued monitoring was performed to limit long-term exposure to this level [13].

The National Institute of Occupational Safety and Health (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 [6]. The American Conference of Government Industrial Hygienists (ACGIH) has also adopted a TWA of 0.1 f/cc as its threshold limit value [14].

EPA has set a maximum contaminant level (MCL) for asbestos fibers in water of 7,000,000 fibers longer than 10 µm per liter, based on an increased risk of developing benign intestinal polyps [15].

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

Asbestos is a known human carcinogen. Historically, EPA has calculated an inhalation unit risk for cancer (cancer slope factor) of 0.23 per f/cc of asbestos [7]. This value estimates additive risk of lung cancer and mesothelioma using a relative risk model for lung cancer and an absolute risk model for mesothelioma. This quantitative risk model has significant limitations. First, the unit risks were based on measurements with phase contrast microscopy and therefore cannot be applied directly to measurements made with other analytical techniques. Second, the unit risk should not be used if the air concentration exceeds 0.04 f/cc, since above this concentration the slope factor might differ from that stated [7]. Perhaps the most significant limitation is that the model does not consider mineralogy, fiber size distribution, or other physical aspects of asbestos toxicity. EPA is in the process of updating their asbestos quantitative risk methodology given the limitations of the current assessment and the knowledge gained since it was implemented in 1986.

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Appendix B - Shipping Information - Libby Vermiculite			
Invoice Date	**Description**	**Qty (Tons)**	**Qty (Lbs)**
11-Dec-68	Hopper (3) No. 3 Crude** Vermiculite	54.65	109,300
3-Oct-69	Hopper (1) No. 1 Crude** Vermiculite	50.00	100,000
22-Jan-70	Hopper (1) No. 1 Crude Vermiculite	50.43	100,860
28-Jan-70	Hopper (3) No. 3 Crude Vermiculite	52.85	105,700
6-Dec-71	Hopper (1G) Crude Vermiculite	57.05	114,100
21-Feb-72	Hopper (1) No. 1 Crude Vermiculite	52.20	104,400
19-May-72	Hopper (3) No. 3 Crude Vermiculite	52.75	105,500
8-Sep-72	Hopper (3) No. 3 Crude Vermiculite	53.65	107,300
13-Nov-72	Car (1) No. 1 Crude Vermiculite	55.30	110,600
20-Sep-73	Hopper (1) No. 1 Crude Vermiculite	51.10	102,200
7-Dec-73	Hopper (1) No. 1 Crude Vermiculite	52.30	104,600
29-Apr-74	No. 1 Crude Vermiculite	57.00	114,000
Source: Unpublished information from EPA's database of W.R. Grace invoices		*** 639.28 Total Tons** **(425.38 tons No. 1 & 213.9 tons No. 3)**	**1,278,560 lbs.**

* The 639.2 tons of Libby vermiculite exfoliated at Supreme Perlite (an average of 91 tons per year for 7 years) is very small compared with other sites, such as Vermiculite Northwest in Portland, Oregon, which exfoliated over 190,000 tons.

** Vermiculite ore is graded from 1 to 5 based on the size of the ore. Some studies have suggested that the different ore grades may have had varying asbestos contents, with finer-sized grades having higher contamination [8, 10].
The owner and a former employee described the vermiculite ore processed at Supreme Perlite as being flakes approximately 1/8 to ¼ inch in size.

Appendix C – Schematic of Vermiculite Processing at Supreme Perlite

Appendix D – Sampling Locations

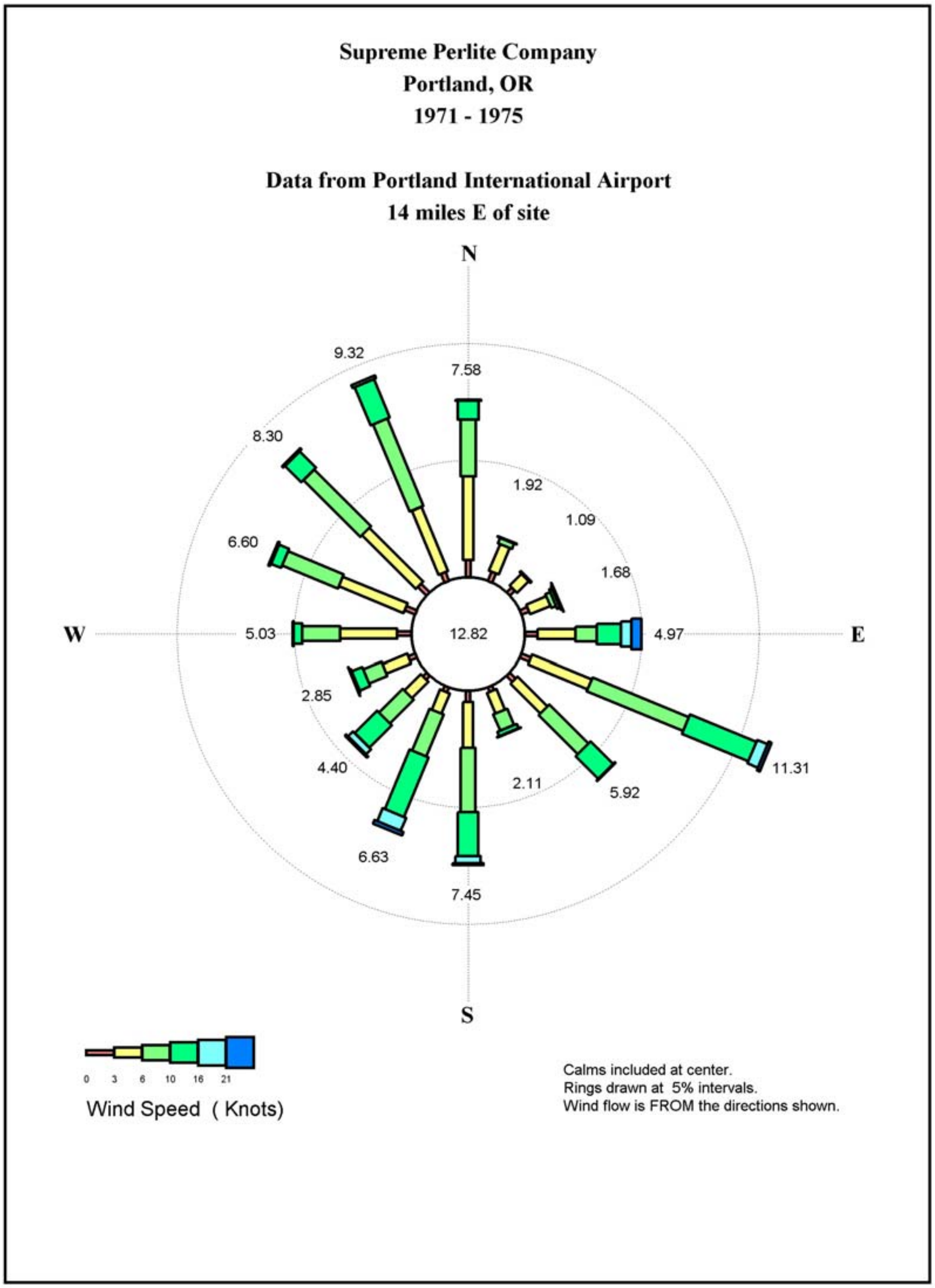
Appendix E – Portland Precipitation Totals 1968-1974

Monthly and Annual Precipitation Totals Portland, Oregon 1968-1974													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1968	4.6	6.6	2.68	1.9	3.6	2.2	0.1	4.53	2.2	5.03	6.23	**11.1***	50.89
1969	**7.6**	**3.1**	**1.13**	2.3	1.6	2.99	0.1	0.04	3.86	**3.02**	**3.18**	**8.12**	37.11
1970	**12**	**4.8**	**2.58**	2.9	1.6	0.49	0.1	trace	1.1	**2.85**	**5.72**	**7.49**	41.35
1971	**7.1**	**3.4**	**4.87**	2.7	1	1.76	0.3	0.95	3.53	**2.37**	**5.76**	**8.05**	41.72
1972	**5.7**	**4.1**	**5.41**	3	2.2	0.68	0.6	0.67	3.06	**0.87**	**3.78**	**8.79**	38.82
1973	**3.7**	**1.9**	**2.45**	1.3	1.4	1.45	0.1	1.41	3.29	**3.14**	**11.6**	**9.93**	41.67
1974	**8.5**	**4.6**	**5.65**	1.8	1.7	0.8	2	0.07	0.21	2.14	6.73	6.05	40.28

SOURCE: National Weather Service Portland, Oregon
(Units are inches)

***** Bolded numbers represent the primary months and years when Libby vermiculite was exfoliated at Supreme Perlite.

Appendix F – Wind Rose



Appendix G - Hazard Category Definitions

Public health hazard categories are statements about 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 no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

No apparent public health hazard
A category used in ATSDR's public health 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 public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Public health hazard
A category used in ATSDR's public health 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 public health 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.

Appendix H - Source For All Pathways: Libby Asbestos-Contaminated Vermiculite from Libby, Montana

PATHWAY NAME	ENVIRONMENTAL MEDIA & TRANSPORT MECHANISMS	POINT OF EXPOSURE	ROUTE OF EXPOSURE	EXPOSURE POPULATION	TIME
Occupational	Suspension of Libby asbestos fibers or contaminated dust into air during materials transport and handling operations or during processing operations	Onsite	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	Past, 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	Onsite, at waste piles	Inhalation	Former or current workers and community	Not applicable
Onsite Soils	Suspension of Libby asbestos fibers into air from disturbing contaminated material remaining in onsite soils (residual soil contamination, buried waste)	At areas of remaining contamination at or around the site	Inhalation	Current onsite workers, contractors	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 offsite for personal uses (gardening, paving driveways, traction, fill)	Residential yards or driveways	Inhalation	Workers and/or community members	Not applicable
Residential Indoor	Suspension of household dust containing Libby asbestos fibers from plant emissions, workers' clothing, or residential outdoor waste	Residences	Inhalation	Community members, former and/or current workers' families and other household contacts	Past
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 I- Supreme Perlite Fact Sheet

Appendix J- Glossary of Environmental Health Terms

Actinolite
A mineral in the amphibole group, a calcium magnesium (iron) silicate with the chemical formula: $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$. The mineral occurs as a series in which magnesium and iron can freely substitute for each other. Actinolite is the intermediate member; when iron is predominant the mineral is ferro-actinolite and when magnesium is predominant, the mineral is tremolite. The iron produces a green color that darkens as the iron content increases. Actinolite may occur in fibrous form (an asbestos). It is not used commercially, but is a common impurity in chrysotile asbestos.

Acute Exposure
Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to14 days.

Adverse Health Effect
A change in body function or the structures of cells that can lead to disease or health problems.

Amosite
A type of asbestos in the amphibole group; it is also known as brown asbestos.

Amphibole
The group name for a family of naturally-occurring ferromagnesium silicate minerals, characterized by a double chain of silicate ions. This group includes tremolite, amosite, actinolite, and crocidolite forms of asbestos. The amphibole group, however, includes a much broader and larger variety of minerals than the asbestiform ones. Amphibole asbestos particles are generally brittle and often have a rod- or needle-like shape.

Anthophyllite
A type of asbestos in the amphibole group; it is also known as azbolen asbestos.

Asbestiform
Possessing the properties of asbestos. A habit of crystal aggregates displaying the characteristics of asbestos: groups of separable, long, thin, strong, and flexible fibers often arranged in parallel in a column or in matted masses. Mineralogists call asbestiform amphibole minerals by their mineral name followed by "asbestos." Thus, asbestiform amosite is called amosite asbestos.

Asbestos
A group of highly fibrous minerals with separable, long, thin fibers often arranged in parallel in a column or in matted masses. Separated asbestos fibers are generally strong enough and flexible enough to be spun and woven, are heat resistant, and are chemically inert. Currently, U.S. regulatory agencies recognize six asbestos minerals: the serpentine mineral, chrysotile; and five asbestiform amphibole minerals, actinolite asbestos, tremolite asbestos, anthophyllite asbestos, amosite asbestos (also known as asbestiform cummingtonite-grunerite), and crocidolite asbestos (also known as asbestiform riebeckite).

Asbestosis
Interstitial fibrosis of the pulmonary parenchymal tissue in which asbestos bodies (fibers coated with protein and iron) or uncoated fibers can be detected. Pulmonary fibrosis refers to a scar-like tissue in the lung that does not expand and contract like normal tissue. This makes breathing difficult. Blood

flow to the lung can also be decreased, and this causes the heart to enlarge. People with asbestosis have shortness of breath, often accompanied by a persistent cough. Asbestosis is a slow-developing disease that can eventually lead to disability or death in people who have been exposed to high amounts of asbestos over a long period. Asbestosis is not usually of concern to people exposed to low levels of asbestos.

Aspect Ratio
Length to width ratio.

ATSDR
The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level
An average or expected amount of a chemical in a specific environment, or amounts of chemicals that occur naturally in a specific environment.

Cancer
A group of diseases that occur when cells in the body become abnormal and grow, or multiply, out of control

Cancer Slope Factor (CSF)
The slope of the dose-response curve for cancer. Multiplying the CSF by the dose gives a prediction of excess cancer risk for a contaminant.

Carcinogen
Any substance shown to cause tumors or cancer in experimental studies.

Chronic Exposure
A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Chrysotile
A fibrous member of the serpentine group of minerals. Chrysotile asbestos fibers are flexible and have a curved morphology. It is the most common form of asbestos used commercially, also referred to as white asbestos.

Completed Exposure Pathway
See **Exposure Pathway**.
Concentration
How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant
See **Environmental Contaminant**.

Crocidolite
A type of asbestos in the amphibole group; it is also known as blue asbestos.

Dermal Contact
Contact by skin with a chemical. (See **Route of Exposure.**)

Dose
The amount of a substance to which a person might be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day."

Duration
The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant
A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than the **Background Level**, or what would be expected.

Environmental Media
Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

US Environmental Protection Agency (EPA)
The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Exposure
Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment
The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway
A description of the way a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Fiber
Any slender, elongated mineral structure or particle. For the purposes of counting asbestos fibers in air samples, regulatory agencies commonly count particles that have lengths >5 µm and length:width

ratios >3:1 as fibers. For detecting asbestos fibers in bulk building materials, particles with length:width ratios >5:1 are counted as fibers.

Fibrous
A mineral habit with crystals that look like fibers. A mineral with a fibrous habit is not asbestiform if the fibers are not separable and are not long, thin, strong, and flexible.

Frequency
How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Friable ACM
Friable **a**sbestos-**c**ontaining **m**aterial is any asbestos-containing material that can be crumbled, pulverized or reduced to powder by hand pressure when dry. Friable asbestos material includes any asbestos-containing material that is shattered or subjected to sanding, grinding, sawing, abrading, or has the potential to release asbestos fibers.

Hazardous Waste
Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Consultation (HC)
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical (compare with Public Health Assessment).

Health Education
Programs designed with a community to help the community know about health risks and how to reduce these risks.

Health Effect
ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).
Ingestion
Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (see **Route of Exposure**).

Inhalation
Breathing. It is a way a chemical can enter your body (see **Route of Exposure**).

Interstitial
A term used as an adjective relating to spaces within a tissue or organ. Pulmonary interstitial fibrosis refers to fibrosis (scarring) developing within lung tissue.

Mesothelioma
Cancer of the thin lining surrounding the lung (the pleura) or the abdominal cavity (the peritoneum). Mesotheliomas are rare cancers in the general population.

Mineral
Any naturally occurring, inorganic substance with a crystal structure.

NPL
The **N**ational **P**riorities **L**ist is a list kept by EPA of the most serious uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or at least looked at to see if people can be exposed to chemicals from the site.

ODEQ
Oregon **D**epartment of **E**nvironmental **Q**uality. The state agency that develops and enforces environmental laws to protect the environment and public health.

ODHS
Oregon **D**epartment of **H**uman **S**ervices. The state public health agency; ODHS has a cooperative agreement with ATSDR to conduct health assessments and consultations at Superfund/NPL and other hazardous waste sites in Oregon through the Superfund Health Investigation and Education (SHINE) program.

Parenchyma
The functional cells or tissue of a gland or organ; for example, the lung parenchyma. The major lung parenchymal abnormality associated with exposure to asbestos is the development of scar-like tissue referred to as pulmonary interstitial fibrosis or asbestosis.

Perlite
A naturally occurring siliceous rock that expands 4 to 20 times its original size when rapidly heated to approximately 3,000 ºF.

PLM
Polarized **L**ight **M**icroscopy is standard method used to quantify asbestos fibers.

Pleura
A thin lining or membrane around the lungs or chest cavity. This lining can become thickened or calcified in asbestos-related disease.

Pleural
Having to do with or involving the pleura.

Pleural abnormalities
Abnormal or diseased changes occurring in the pleura. Pleural abnormalities associated with exposure to asbestos include pleural plaques, pleural thickening or calcifications, and pleural effusion.

Pleural calcification
As a result of chronic inflammation and scarring, pleura becomes thickened and can calcify. White calcified areas can be seen on the pleura by X-ray.

Pleural cavity
The cavity, defined by a thin membrane (the pleural membrane or pleura), which contains the lungs.

Pleural effusion
Cells (fluid) can ooze or weep from the lung tissue into the space between the lungs and the chest cavity (pleural space) causing a pleural effusion. The effusion fluid can be clear or bloody. Pleural effusions may be an early sign of asbestos exposure or mesothelioma and should be evaluated.

Pleural plaques
Localized or diffuse areas of thickening of the pleura (lining of the lungs) or chest cavity. Pleural plaques are detected by chest x-ray, and appear as opaque, shiny, and rounded lesions.

Pleural thickening
Thickening or scarring of the pleura that might be associated with asbestos exposure. In severe cases, the normally thin pleura can become thickened like an orange peel and restrict breathing.

Point of Exposure
The place where someone can come into contact with a contaminated environmental medium (air, water, food, or soil). Some examples include the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, or the backyard area where someone might breathe contaminated air.

Public Health Assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with Health Consultation].

Pulmonary interstitial fibrosis
Scar-like tissue that develops in the lung parenchymal tissue in response to inhalation of dusts of certain types of substances such as asbestos.

Route of Exposure
The way a chemical can get into a person’s body. The three exposure routes are:

- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- getting something on the skin (also called dermal contact).

SEM
Scanning **e**lectron **m**icroscopy

Serpentine
A name given to several members of a polymorphic group of magnesium silicate minerals. Chrysotile asbestos is a fibrous member of the serpentine group. "Serpentine" comes from mottled shades of green on massive varieties, suggestive of snake markings.

SHINE
Superfund **H**ealth **In**vestigation and **E**ducation program. The Oregon Department of Human Services program that, through a cooperative agreement with ATSDR, works with communities and agencies to evaluate and prevent health effects from exposure to hazardous substances.

Source (of Contamination)
The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Superfund
See **NPL.**

TEM
Transmission **e**lectron **m**icroscopy

Toxic
Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Tumor
Abnormal growth of tissue or cells that have formed a lump or mass.

Vermiculite
A chemically inert, lightweight, fire resistant, and odorless magnesium silicate material that is generally used for its thermal and sound insulation in construction and for its absorbent properties in horticultural applications. In a process called exfoliation, raw vermiculite is rapidly heated to a temperature above 870º C. The mica-like flakes of vermiculite concentrate, which contain interlayers of water, then expand into accordion-like particles as the water is converted into steam. Vermiculite mined from Libby, Montana has been demonstrated to contain various amounts of asbestiform tremolite-like amphibole minerals.