Health Consultation

FORMER VERMICULITE OF HAWAII SITE
842-A MAPUNAPUNA STREET

HONOLULU, HAWAII

EPA FACILITY ID: HIN000905638

SEPTEMBER 22, 2005

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

Health Consultation: A Note of Explanation

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

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

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR
or
Visit our Home Page at: http://www.atsdr.cdc.gov

HEALTH CONSULTATION

FORMER VERMICULITE OF HAWAII SITE
842-A MAPUNAPUNA STREET

HONOLULU, HAWAII

EPA FACILITY ID: HIN000905638

Prepared by:

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

Foreword: ATSDR's National Asbestos Exposure Review

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

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

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

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

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

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

- or -

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

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

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

Executive Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the Vermiculite of Hawaii site in Honolulu, Hawaii, because the Environmental Protection Agency (EPA) identified the site for further action on the basis of contamination found at the site during their investigations in 2000 and 2001. Vermiculite of Hawaii received asbestos-contaminated vermiculite from the Libby mine and processed it by exfoliation. Commercial exfoliation of vermiculite is a process of heating it in a furnace to expand or "pop" it into lightweight nuggets.

Vermiculite of Hawaii operated as a vermiculite exfoliation facility during 1954–1983. Other businesses have leased the facility since then. The site consists of four buildings on approximately 0.8 acres of land. Most of the site is covered by the buildings and paved surfaces, although some areas of grass and uncovered soil are located on the edges of the property. Current land use surrounding the site is primarily commercial and industrial. The closest residential properties are in a military housing area a few hundred yards west of the site. This residential development was present at least part of the time the facility processed vermiculite.

While the facility was operating, workers at the facility and members of their households were exposed to asbestos from the processing and handling of asbestos-contaminated vermiculite and waste rock. At similar exfoliation facilities, these exposure pathways are considered a public health hazard on the basis of available information concerning the intensity, frequency, and duration of past occupational exposures. ATSDR does not have site-specific exposure data for the Vermiculite of Hawaii facility; however, enough similarities exist between this site and other exfoliation sites for which data are available to warrant taking similar public health actions at the site. Examples of such actions include promoting awareness about potential exposures to asbestos and providing health education to former workers and their household contacts.

After the Honolulu facility stopped exfoliating vermiculite in 1983, some residual asbestos remained inside the building and in soil on the site. Other businesses have leased the site since then. Employees at the site could have been exposed to residual asbestos during 1983–2001, however insufficient information is available to characterize the exposure. ATSDR recommends that employees who worked at the site during 1983–2001 be advised of their potential exposure to asbestos. Areas of residual asbestos were remediated in November and December 2001, therefore current and future worker exposure pathways were eliminated and no longer pose a public health hazard.

Community members who lived or worked near the Vermiculite of Hawaii facility while it was operating could have been exposed to Libby asbestos in a variety of ways. Very little information is available to verify community exposure or to quantify the magnitude, frequency, or duration of the exposure. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached the adjacent residential area during 1954–1983 and (2) piles of waste rock on the site that may have been accessible to community members, especially children. Children who were exposed to asbestos are a population of particular concern because of the length of time the asbestos fibers remain in their lungs and the long latency of asbestos-related diseases.

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

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

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

Background

ATSDR evaluated the former Vermiculite of Hawaii site (Honolulu facility) because EPA identified the site for further action on the basis of contamination found at the site during their investigations in 2000 and 2001 [1, 2]. Available invoice data indicate the facility received over 6,000 tons of vermiculite during 1967–1983 (EPA, unpublished data, 2001).[1] Invoice records were not available for this site for the time period before 1967.

Vermiculite of Hawaii operated as a vermiculite exfoliation facility during 1954–1983 [3] (EPA, unpublished data).[2] For at least part of that time, the company had a sales and trademark licensing agreement with W.R. Grace & Company (W.R. Grace) (EPA, unpublished data). The exfoliated vermiculite produced by the facility was used as insulation, plaster and concrete aggregate, and in agricultural products [4, 5].

Vermiculite of Hawaii exfoliated vermiculite at the 842A Mapunapuna Street, Honolulu, location at least as early as 1967 [4]. The site address for Vermiculite of Hawaii before 1967 cannot be confirmed. The buildings located at 842 Mapunapuna Street have been leased to other businesses since Vermiculite of Hawaii vacated the site in 1983 [1]. One or more of the buildings on the site may have been leased separately to other businesses even during the time Vermiculite of Hawaii operated there [1].

EPA Region 9 site investigations in 2000 and 2001 included collection and analysis of air, dust, bulk material, and soil samples from the site [1, 2]. On basis of the findings, the current owner worked with EPA Region 9 to remove several areas of asbestos-contaminated soil, dust, and bulk material (vermiculite) at the site [6]. EPA Region 9 issued a final report indicating that the cleanup was complete and no further action was required [7].

Site description

The former Honolulu facility site is located at 842A Mapunapuna Street in Honolulu, Hawaii, approximately 1 mile northeast of the Honolulu International Airport (Figure 1). The site consists of four buildings on approximately 0.8 acres of land (Figure 2) [2]. Most of the site is covered by the buildings and paved surfaces; some areas of grass and uncovered soil are located on the edges of the site [2].

The site is bordered by other commercial/industrial properties to the north and south, by Mapunapuna Street to the east, and by Puuloa Road to the west. Current land use surrounding the site is a mixture of commercial and industrial. The closest residential properties are in a military housing area located within a few hundred yards west of the site (Figures 1 and 3). This residential area is visible in aerial photographs dating back to at least 1974 [8]. According to 2000 census data, more than 50% of the homes in the vicinity of the site were constructed before 1980 [9]. Census data from 1990 indicate that 23,317 people lived within 1 mile of the facility (Figure 3).

---

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

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

Honolulu area temperatures are mild throughout the year, ranging from an average maximum temperature of 84.0 degrees Fahrenheit to an average minimum of 70.2 degrees Fahrenheit [10]. Normal annual precipitation for Honolulu is about 20 inches [10]. Persistent trade winds flow in a general east-to-west direction across the islands of Hawaii, although the mountainous terrain creates complex local wind regimes. Meteorologic data from the Honolulu Airport suggest the predominant wind direction for that area is from the northeast (Figure 4). The site is 2 miles northeast of the airport; therefore, actual conditions at the site could vary due to local topography and other factors.

Vermiculite exfoliation

The U.S. Geological Survey describes vermiculite as "… a general term applied to a group of platy minerals that form from the weathering of micas by ground water. Their distinctive characteristic is a prominent accordion-like unfolding and expansion when heated … the [expanded] vermiculite material is very lightweight and possesses fire- and sound-insulating properties. It is thus well suited for many commercial applications."[11]

The vermiculite ore mined in Libby, Montana, was concentrated and milled to produce different sizes, or grades, of vermiculite. This milled vermiculite was then shipped to the Honolulu facility and to other processing facilities throughout the country. Before milling, the raw vermiculite from the Libby mine contained up to 26% asbestos [12]. The various grades of milled vermiculite shipped from Libby contained fibrous amphibole asbestos at concentrations ranging from 0.3% to 7.0% [12].

The vermiculite exfoliation process information presented in the following paragraphs was derived from Bureau of Mines reports as well as unpublished documents pertaining primarily to exfoliation facilities managed by W.R. Grace. W.R. Grace owned and operated the Libby mine and several dozen vermiculite exfoliation facilities from 1963 to the early 1990s.

Commercial exfoliation of vermiculite is a process that can be likened to popping popcorn. Vermiculite is heated in a furnace to temperatures of 1,500 degrees to 2,000 degrees Fahrenheit. As water molecules within the mineral structure are driven off, the vermiculite expands into lightweight, accordion-like nuggets (Figure 5) [11]. The unpopped material that remains after the vermiculite is expanded is called waste rock or stoner rock (Figure 6). Estimates of the asbestos content of the waste rock vary from 2% to 10% (EPA, unpublished data; J. Kelly, Minnesota Department of Health, personal communication, 2002).

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

Equipment and operational changes were implemented at many vermiculite exfoliation facilities in response to environmental and worker regulations promulgated throughout the 1970s.

Although asbestos emissions from these exfoliation facilities were not regulated under 1970 EPA Clean Air Act amendments, W.R. Grace submitted information to EPA in May 1973 indicating that 19 of their 31 exfoliation facilities had particulate and asbestos emission control equipment that was compliant with the regulations (EPA, unpublished data). As the Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL) for occupational exposure to asbestos steadily decreased from an initial standard of 12 fibers per cubic centimeter of air (f/cc) established in 1971 to the 1994 standard of 0.1 f/cc [13], W.R. Grace initiated employee monitoring and various process design changes to achieve compliance (EPA, unpublished data).

At some exfoliation facilities owned by W.R. Grace, respiratory protection (such as dust masks and various types of respirators) was periodically documented for certain job categories in industrial hygiene reports dating back to the early 1970s (EPA, unpublished data). Information is not available to evaluate the use or effectiveness of this respiratory equipment in reducing workers' exposure to asbestos. The overall effectiveness depends on a number of factors, including the protection factor of the masks, the effectiveness of the fit testing protocols, and the actual compliance of individuals required to wear the masks.

Records indicate waste rock and fine particulates from the dust and fiber control equipment at many of the W.R. Grace exfoliation facilities was bagged and disposed of at local landfills beginning in the late 1970s and early 1980s [14]. Before that time, little information is available to track the handling and disposal of waste rock and fine particulates at these facilities. Anecdotal reports indicate the waste rock at some facilities was temporarily stockpiled on the site; these stockpiles were accessible to the public, and children played in them [15, 16]. At one exfoliation facility, workers and nearby community members were encouraged to take waste rock home for personal use [15].

Asbestos and asbestos-related health effects

Asbestos minerals fall into two groups, serpentine and amphibole. Serpentine asbestos has relatively long and flexible crystalline fibers; this class includes chrysotile, the predominant type of asbestos used commercially. Fibrous amphibole asbestos minerals are brittle and have a rod- or needle-like shape. Amphibole minerals regulated as asbestos by OSHA include five classes: crocidolite, amosite, and the fibrous forms of tremolite, actinolite, and anthophyllite. Other unregulated amphibole minerals, including winchite, richterite, and others, can also exhibit fibrous asbestiform properties [11].

Vermiculite from Libby was found to contain several types of asbestos fibers, including the amphibole asbestos varieties tremolite and actinolite and the related fibrous asbestiform minerals winchite, richterite, and ferro-edenite [11]. In this report, the terms Libby asbestos and Libby amphibole will be used to refer to the characteristic composition of asbestos contaminating the vermiculite from Libby.

Individual asbestos fibers are too small to be seen without a microscope or other laboratory instruments. However, asbestos can sometimes be visible when many fibers form together in "bundles" or when the minerals form in nonfibrous blocky fragments (Figure 6). Asbestos fibers do not have a detectable odor or taste. They do not dissolve in water or evaporate into the air, although individual asbestos fibers can easily be suspended in the air. Asbestos fibers do not move through soil. They are resistant to heat, fire, and chemical and biological degradation. As such, they can remain virtually unchanged in the environment over long periods of time [17].

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

In terms of human exposure, ATSDR considers the inhalation route of exposure to be the most significant in the current evaluation of sites that received vermiculite from Libby. Although both ingestion and dermal exposure routes may exist, health risks from these exposures are low compared with health risks from the inhalation route [17]. Health effects associated with breathing asbestos include the following:

- *Malignant mesothelioma*—Cancer of the membrane (pleura) that encases the lungs and lines the chest cavity. This cancer can spread to tissues surrounding the lungs or other organs. The majority of mesothelioma cases are attributable to asbestos exposure [17].
- *Lung cancer*—Cancer of the lung tissue, also known as bronchogenic carcinoma. The exact mechanism relating asbestos exposure with lung cancer is not completely understood. The combination of tobacco smoking and asbestos exposure greatly increases the risk for lung cancer [17].
- *Noncancer effects*—These include asbestosis (scarring of the lung, and reduced lung function caused by asbestos fibers lodged in the lung); pleural plaques (localized or diffuse areas of thickening of the pleura); pleural thickening (extensive thickening of the pleura, which may restrict breathing); pleural calcification (calcium deposition on pleural areas thickened from chronic inflammation and scarring); and pleural effusions (fluid buildup in the pleural space between the lungs and the chest cavity) [17].

Numerous studies of occupationally exposed workers conclusively demonstrate that inhalation of asbestos can increase the risk for mesothelioma, lung cancer, and various noncancer effects [17]. Several studies have documented health impacts consistent with asbestos-related disease in workers and others associated with the Libby mine [18-23]. Asbestos-related health impacts to workers associated with vermiculite exfoliation facilities have also been documented [24, 25].

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 [17]. The mineralogy and size of the asbestos fibers involved in the exposure are also important in determining the likelihood and nature of potential health impacts. Exposure to amphibole asbestos fibers that are long (greater than 10 micrometers) increases the risk for carcinogenic health effects such as mesothelioma and lung cancer [17, 26, 27]. Short amphibole fibers (less than 5 micrometers) are thought to be less important in inducing carcinogenic effects, but they may play a role in increasing the risk for noncancer effects such as asbestosis [28]. The fibrous forms of amphibole asbestos are potentially more toxic than other commonly encountered serpentine fibers (for example, chrysotile) [17, 27, 29].

Chronic exposure is a significant risk factor for asbestos-related disease. However, brief episodic exposures may also contribute to disease. A brief, high intensity exposure from working just two summers at a vermiculite exfoliation facility in California has been linked to a case of fatal asbestosis [25]. Very little conclusive evidence is available regarding the health effects of low-dose, intermittent exposures to asbestos. A “safe” exposure level below which health effects are unlikely has yet to be formally defined in federal regulations and policies.

Methods

Data sources

ATSDR obtained site-specific environmental and facility operational data from EPA. ATSDR also acquired various operational and technical data for the Honolulu site from a database of W.R. Grace documents that EPA Region 8 obtained during the investigation of the Libby mine. This document database, comprising approximately 2.5 million electronic image files, contains confidential business information as well as private information that is not available to the public.

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

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

Site evaluation methodology

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

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

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

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

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

For asbestos fiber levels in air, ATSDR used the current risk-based OSHA PEL of 0.1 fibers per cubic centimeter (f/cc) of air as one metric to assess asbestos inhalation exposure for workers [13]. The 0.1 f/cc OSHA PEL, calculated as an 8-hour time-weighted average, represents the upper limit of exposure for a worker during a normal work day. It is worthwhile to note that OSHA’s final rules for occupational exposure to asbestos acknowledged that “…a significant risk remains at the PEL of 0.1 f/cc” [13]. Instead of reducing the PEL even further, OSHA elected to eliminate or reduce this risk through mandated work practices, including engineering controls and respiratory protection for various classifications of asbestos-related construction activities [13].

ATSDR acknowledges two community exposure guidelines for airborne asbestos established by interagency workgroups following the World Trade Center collapse in 2001. For short-term (less than 1 year) exposures, 0.01 f/cc asbestos in indoor air was developed as an acceptable reoccupation level for occupants of residential buildings [30]. A risk-based comparison value of 0.0009 f/cc for asbestos in indoor air was established to be protective under long-term residential exposure scenarios [31]. All three exposure values (the OSHA PEL and the two World Trade Center community guidance values) are primarily applicable to airborne chrysotile asbestos fibers which have lower toxicity than Libby asbestos.

In the absence of any health- or risk-based comparison levels for asbestos in soil, dust, or bulk materials, ATSDR is evaluating these exposure pathways qualitatively, with strong consideration given to known or potential exposure scenarios at each site. For example, to determine whether asbestos in soil poses a public health hazard at a site, ATSDR is considering the concentration of asbestos in the soil, the horizontal extent of asbestos-contaminated surface areas, the presence or absence of ground cover, the frequency and type of activities that disturb soil, and accessibility. Soil containing Libby asbestos at levels greater than or equal to 1% is generally considered a health hazard requiring remediation. Depending on site-specific exposure scenarios, remediation or other measures may also be appropriate to prevent exposure to soil containing less than 1% Libby asbestos. Because federal standards regulate materials that contain more than 1% asbestos [32, 33], the 1% value has been used as an action level for soil remediation activities at a number of sites. EPA and ATSDR recognize that this 1% value is not derived from a health-based analysis; therefore, it does not ensure that airborne asbestos fibers resuspended by disturbing these soils will be below levels protective of human health [34]. In fact, recent activity-based studies have shown that disturbing soil containing less than 1% Libby asbestos can resuspend fibers and generate localized airborne concentrations at or near the OSHA permissible exposure limit [35, 36].

Results

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

Table 2: Summary of pathway evaluations for the Honolulu site

Pathway Name	*Exposure Scenario*	*Timeframe*	*Pathway Status**	*Public Health Hazard Determination**
Occupational	Former workers inhaling Libby asbestos in and around the facility during handling and processing of contaminated vermiculite	**Past (1954–1983)**	**Complete**	**Public health hazard**
		Recent past (1983–2001)	Potential	Indeterminate
	Current on-site workers inhaling Libby asbestos from residual contamination inside former processing buildings or in on-site soil (residual contamination, buried waste)	Present/ Future	Eliminated	No public health hazard
Household Contact	Household contacts inhaling Libby asbestos brought home on workers' clothing, shoes, and hair	**Past (1954–1983)**	**Complete**	**Public health hazard**
		Recent past (1983–2001)	Potential	No apparent public health hazard
		Present/ Future	Eliminated	No public health hazard
Community	Facility emissions: Community members or nearby workers inhaling asbestos fibers from plant emissions during handling and processing of contaminated vermiculite	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	Waste piles: Community members (particularly children) inhaling asbestos while playing in or disturbing on-site piles of contaminated vermiculite or waste rock	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	On-site soil: Community members inhaling Libby asbestos from contaminated on-site soil (residual contamination, buried waste)	Past	Potential	Indeterminate
		Present/ Future	Eliminated	No public health hazard
	Residential outdoor: Community members inhaling Libby asbestos while using contaminated vermiculite or waste material at home (for gardening, driveways, fill material)	Past	Potential	Indeterminate
		Present/ Future	Potential	Indeterminate
	Residential indoor: Community members disturbing household dust containing Libby asbestos fibers from plant emissions or residential outdoor waste	Past	Potential	Indeterminate
		Present/ Future	Potential	No apparent public health hazard

*Pathway status descriptions and public health hazard category definitions are provided in Appendix A.
Bold type indicates a completed pathway that is considered a public health hazard.

Occupational pathway (past: 1954–1983 timeframe)

The occupational exposure pathway for former workers exposed to airborne Libby asbestos in and around the Honolulu facility during handling and processing of vermiculite during 1954–1983 is considered complete. At similar exfoliation facilities, this exposure pathway is considered a public health hazard on the basis of available information concerning the intensity, frequency, and duration of past occupational exposures. At the Honolulu facility, insufficient site-specific data are available to characterize worker exposures to asbestos. Nonetheless, enough similarities exist between this site and other exfoliation sites for which data are available to consider the exposure pathway for former workers a public health hazard.

On the basis of available invoice data, the Honolulu facility received vermiculite from the Libby mine in bags and in bulk shipping containers (EPA, unpublished data, 2001). Information concerning how vermiculite was handled, transported, stored, processed, and packaged at the facility is not available. Vermiculite of Hawaii had a sales and trademark licensing agreement with W.R. Grace [37]; therefore, the exfoliation operations and plant conditions are expected to be similar to those found at exfoliation facilities owned by W.R. Grace. Information pertaining to the W.R. Grace vermiculite exfoliation facilities is discussed in the following paragraphs for reference.

At exfoliation facilities owned and operated by W.R. Grace, personal sampling results available for workers in the 1970s indicate airborne fiber levels consistently in the range of 0.1 f/cc to 1.0 f/cc [38]. These fiber levels were measured using phase contrast microscopy (PCM) analytical techniques.[4] By the mid-1980s, annual measured airborne PCM fiber concentrations from both personal and area sampling inside these facilities were typically below the current OSHA PEL of 0.1 f/cc. Personal samples, typically collected within a worker's breathing zone, were associated with specific workers. Most of the area sampling was conducted at consistent locations in the exfoliation process where fibers were likely to be released (e.g., the furnace baghouse, the furnace stoner deck where waste rock and expanded product were separated, the waste rock hopper) (EPA, unpublished data).

Before the 1970s, air sampling data at exfoliation facilities owned by W.R. Grace are not available, although airborne fiber levels during this period were likely at or above the levels documented in the 1970s (i.e., 0.1 f/cc to 1.0 f/cc). Measured airborne fiber levels within these facilities decreased throughout the 1970s and 1980s as W.R. Grace responded to federal OSHA requirements[5] to protect workers from occupational asbestos exposure (EPA, unpublished data). Asbestos exposure levels for workers could have been much higher before the OSHA regulations were first introduced in 1971. Asbestos exposures would also be higher for workers who manually performed some of the material handling processes, such as unloading vermiculite deliveries from railcars, transferring vermiculite into furnace hoppers, and transferring bulk quantities of waste rock.

The frequency and duration of former worker exposures depended on the workers' job assignments, facility operation schedules, and periods of employment. Exfoliation facilities were dedicated almost exclusively to processing vermiculite for 8 to 24 hours a day, 5 to 7 days a week [15, 38]. Information from some W.R. Grace facilities indicates the workforce consisted of both salaried and hourly employees. The length of employment for exfoliation facility workers is generally unknown, although individual cases of employment for 10 or more years have been documented.

Use of respiratory protection would influence the degree of worker exposure to airborne asbestos fibers at these vermiculite exfoliation facilities. At facilities under W.R. Grace management, respiratory protection programs and worker use of respiratory protection were documented in the

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

[5] Historically, the OSHA PEL for airborne asbestos has been lowered a number of times since it was first introduced: 12.0 f/cc (initial level, May 1971), 5.0 f/cc (December 1971), 2.0 f/cc (July 1976), 0.2 f/cc (June 1986), and 0.1 f/cc (August 1994).

1980s. Information is not available to evaluate the overall effectiveness of respiratory equipment in reducing worker exposures to asbestos at these facilities. Overall effectiveness depends on several factors, including the protection factor of the masks, the effectiveness of the fit testing protocols, and the actual compliance of individuals required to wear the masks.

At other exfoliation facilities, Libby asbestos fibers were released into the indoor air throughout the workday during vermiculite processing and handling. Workers could have been exposed to Libby asbestos outside the facilities as well. Fugitive emissions from loading, unloading, or transferring bulk vermiculite or waste rock resulted in outdoor airborne asbestos fiber releases. Information provided to EPA in 1978 by a (non W.R. Grace) company that exfoliated Libby vermiculite indicated airborne fiber levels were as high as 245 f/cc in the unloading area where unexpanded vermiculite was dumped from rail cars [39]. Stack emissions from exfoliation furnaces also contributed to outdoor fiber releases. In the 1970s and 1980s, W.R. Grace installed air pollution control equipment at many of their facilities to control particulate emissions from the exfoliation furnaces (EPA, unpublished data). The concentrations of particulates and airborne asbestos fibers in outdoor air around the facility that resulted from fugitive and stack emissions were likely much higher before the fiber control equipment was installed.

Various workers probably visited the Honolulu facility periodically to haul waste rock away from the site, purchase products, pick up products for delivery, or provide services (for example, construction and electrical services and equipment maintenance). These workers were probably exposed to airborne asbestos in and around the facility, but the frequency and duration of the exposure was likely very low. Data available from other facilities indicate that waste haulers may have been exposed to asbestos as they loaded and unloaded waste rock (EPA, unpublished data). All of these ancillary worker groups (that is, workers not directly employed at the exfoliation facility) were exposed much less frequently and for shorter durations than the full-time workers at the exfoliation facility.

Occupational pathway (recent past: 1983–2001 timeframe)

Vermiculite of Hawaii stopped exfoliating vermiculite at the site in 1983 (EPA, unpublished data). Other businesses have leased the site since that time. Most sources of Libby asbestos have been eliminated from the site; however, EPA sampling in 2001 indicated areas of residual asbestos remained in some onsite buildings and outside soils. These areas were remediated in November and December 2001 [6]. Workers on the site could have been exposed to residual asbestos in buildings or outside soils during 1983–2001; however, insufficient information is available to characterize these exposures. Exposure pathways involving these areas are considered an indeterminate public health hazard.

Occupational pathway (present/future timeframe)

The areas of residual Libby asbestos identified by EPA at the Honolulu facility have been remediated. Interior remediation was accomplished using a combination of high efficiency particulate air (HEPA) vacuum cleaners and wet techniques. Exterior asbestos-contaminated soil was excavated and removed. Confirmation and clearance sampling were conducted in interior and exterior areas as appropriate [6]. Current and future worker exposure pathways are considered eliminated and therefore pose no public health hazard.

Household contact pathway (past: 1954–1983 timeframe)

Exposure of household contacts to airborne Libby asbestos unintentially brought home on the clothing, shoes, and hair of former workers is considered a complete exposure pathway that represents a public health hazard. Site-specific exposure data are not available for household contacts. However, at similar exfoliation facilities, household contact exposures are inferred from documented former worker exposures and facility conditions that did not prevent contaminants from being brought into the workers' homes [40-42].

Vermiculite exfoliation was reportedly a very dusty operation. Members of the households of former Vermiculite of Hawaii workers were exposed to Libby asbestos fibers brought home on the workers' clothing, shoes, and hair if the workers did not shower or change clothes before leaving work. Family members or other household contacts could have been exposed to asbestos by direct contact with the worker or by laundering clothing. These exposures cannot be quantified without information concerning the levels of asbestos on the workers' clothing and behavior-specific factors (for example, worker practices and household laundering practices). However, exposure to asbestos resulting in asbestos-related disease in family members of asbestos industry workers has been well-documented [43, 44].

Household contact pathway (recent past: 1983–2001 timeframe)

Workers at the site may have been exposed to residual asbestos fibers associated with vermiculite processing buildings or soil on the site. Data are not available to characterize potential exposures to household members who had contact with these workers or their clothing. These workers may have taken home very low concentrations of asbestos. This exposure is considered no apparent public health hazard for household members who had contact with the workers or the workers' clothing.

Household contact pathway (present–after December 2001/future timeframe)

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

Community pathways (past timeframe)

Community members who lived or worked around the Honolulu facility during 1954–1983 could have been exposed to Libby asbestos from facility emissions, by disturbing or playing on on-site waste rock piles, by disturbing on-site soil or from direct contact with waste rock brought home for personal use. Information is insufficient to reconstruct the magnitude, frequency, or duration of these community exposures; therefore, they are considered an indeterminate public health hazard.

Community members and area workers could have been exposed to Libby asbestos fibers released into the ambient air from fugitive emissions or from furnace stack emissions generated while the facility was operating. The wind direction in this area is most commonly from the northeast (Figure 4). Residences within the military housing areas west of the facility may have been downwind some of the time.

Fugitive emissions from loading, unloading, or transferring bulk vermiculite or waste rock resulted in airborne asbestos fiber releases in areas around the facility. Stack emissions from the furnaces also contributed to outdoor fiber releases. Insufficient information is available to determine if any pollution control equipment or practices were implemented at this facility to reduce airborne particulates or fiber emissions. At an exfoliation facility in Weedsport, New York, in 1970, stack test data for an exfoliation furnace without particulate control equipment indicated particulate emission rates of 6 pounds per hour (EPA, unpublished data). Particulates captured by the filters in the pollution control equipment (when installed) at various exfoliation facilities reportedly contained 1%–3% friable Libby asbestos (EPA, unpublished data).

The exposure pathway for community members (particularly children) who played in or otherwise disturbed on-site piles of contaminated vermiculite, waste rock, or on-site soil at the facility in the past is considered to be a potential exposure pathway. When the facility was operating, waste rock may have been temporarily stockpiled on the site and accessible to children and other community members. Anecdotal or photographic evidence of children playing in on-site waste piles is available for several similar exfoliation facilities [15, 16, 45].

Community members' use of contaminated vermiculite or waste material at home is considered a potential exposure pathway. At a former vermiculite exfoliation facility in Minneapolis, Minnesota, waste rock was advertised as "free crushed rock," and community members took it home to use in their yards, gardens, and driveways [15]. Insufficient information is available to determine whether this happened at the Honolulu facility during the time vermiculite was processed there. If so, people may have been exposed to airborne Libby asbestos by handling waste rock and working with it in their yards and gardens.

Libby asbestos fibers could have infiltrated homes surrounding the Honolulu facility as a result of plant emissions or waste rock that was taken home for personal use. Insufficient information is available concerning past air emissions and community use of waste rock. Indoor residential exposure to Libby asbestos fibers in the past is considered an indeterminate public health hazard.

Community pathways (present/future timeframe)

Most community members who live or work near the site now are not being exposed to Libby asbestos from the site. Several community exposure pathways (such as exposure to ambient air emissions, on-site contaminated soils, and on-site vermiculite and waste rock piles) have been eliminated and do not pose a public health hazard.

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

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

Discussion

Exposure pathway evaluations

While the Honolulu facility was operating, the processing and handling of asbestos-contaminated vermiculite resulted in exposure to former workers and their household contacts. Site-specific information is not available to characterize these exposures. However, on the basis of available exposure information for similar facilities, ATSDR considers these exposure pathways a public health hazard and recommends that former workers and household contacts be advised about their exposures and the potential health implications.

The frequency and duration of former worker exposures depended on the workers' job assignments, facility operation schedules, and periods of employment. Use of respiratory protection would also influence the degree of worker exposure to airborne asbestos fibers.

After the Honolulu facility ceased vermiculite exfoliation in 1983, some residual asbestos remained inside the building and in on-site soil. Other businesses have leased the site since then. Employees on the site could have been exposed to residual asbestos during 1983–2001; however, insufficient information is available to characterize these exposures. ATSDR recommends that employees who worked at the site during 1983–2001 be advised about their potential exposure to asbestos during this time. Areas of residual asbestos were remediated in November and December 2001; therefore, current and future worker exposure pathways are considered eliminated and do not pose a public health hazard.

Community members who lived or worked near the Honolulu facility in the past could have been exposed to Libby asbestos from facility emissions, by disturbing or playing on on-site waste rock piles, by disturbing on-site soil, or from coming into direct contact with waste rock brought home for personal use. Very little information is available to verify these community exposures or to quantify their magnitude, frequency, or duration. They are therefore considered an indeterminate public health hazard. The two potential pathways of greatest concern are (1) plant emissions of Libby asbestos that may have reached downwind residential areas during 1954–1983 and (2) on-site waste rock piles that may have been accessible to community members, expecially children.

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

Potential health impacts

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

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

Limitations

A number of site-specific limitations affect the exposure pathway evaluation and health risk characterization efforts at the Honolulu site. Exposure data are not available for most of the past and current exposure pathways. This information may never be available for some of the past exposure scenarios. Site-specific exposure data were available for former workers at other exfoliation facilities operated by W.R. Grace. Since Vermiculite of Hawaii operated under a sales and trademark licensing agreement with W.R. Grace, ATSDR assumed that the vermiculite handling and processing operations, as well as the former worker exposures, were similar.

Limitations in the current state of science related to amphibole asbestos influence the evaluation of exposure to Libby asbestos and the potential for health risks associated with the exposure. Health-based comparison values representing "safe" levels of amphibole asbestos in air have not been developed. Determining "safe" levels of asbestos in other environmental media (soil or dust) is even more difficult because a safe level is not determined by the inherent asbestos fiber or mass concentration in the medium itself, but rather on the potential airborne fiber exposure associated with disturbing asbestos-contaminated soil or dust.

A practical model or empirical relationship to estimate the resuspension of asbestos fibers from solid media (for example, soil or dust) into air during realistic exposure scenarios does not exist. Two options are available to estimate the resuspension of asbestos fibers from soil or dust into air during realistic exposure scenarios, but they are both relatively difficult and costly to implement. One option is to conduct site-specific, activity-based field tests that directly measure airborne fiber levels during simulated exposure scenarios. The other option is to collect site-specific soil samples, analyze them in accordance with EPA 540/R/97/28[6] to obtain the fraction of fibers in the soil that can be released into the air, and then use this information in an appropriate air modeling effort to simulate exposure scenarios.

An adequate toxicological model to evaluate the noncarcinogenic health risks of amphibole asbestos exposure does not exist. The current EPA model used to quantify carcinogenic health

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

risks associated with asbestos exposure has significant limitations, including the fact that it does not consider mineralogy or fiber size distribution and it combines lung cancer and mesothelioma risk into one slope factor. EPA is in the process of updating their asbestos risk methodologies. A draft model for quantifying carcinogenic health risks associated with amphibole asbestos has been developed [26], although it has not been formally accepted through the EPA review process. This draft methodology requires detailed asbestos sample characterization beyond what was generated at these vermiculite sites. Data gaps in scientific research concerning Libby asbestos have resulted in ongoing and largely unresolved discussions in the scientific community regarding the potential health risks of low-level, intermittent exposures and the relative importance of short asbestos fibers (fibers less than 5 micrometers in length) in noncancer health effects [27, 28].

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

Public health response

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

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

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

Conclusions, recommendations, and public health action plan

Former workers and their household contacts (1954–1983)

People who worked at the Vermiculite of Hawaii facility during 1954–1983 were exposed to airborne levels of Libby asbestos. At similar exfoliation facilities, this exposure pathway is considered a public health hazard on the basis of available information concerning the intensity, frequency, and duration of past occupational exposures. Site-specific exposure data are not available to characterize the exposures at Vermiculite of Hawaii. However, enough similarities exist between this site and other exfoliation sites for which data are available to consider former worker exposure a *public health hazard*.

In the past, members of the households of former workers may have been exposed to asbestos fibers if the workers did not shower or change clothes before leaving work. At similar exfoliation facilities, household contact exposure to asbestos is considered a public health hazard on the basis of inferences from the documented worker exposure. Site-specific exposure data are not available for the Vermiculite of Hawaii facility. However, enough similarities exist between this site and other exfoliation sites for which data are available to consider household contact exposure to asbestos a *public health hazard*.

Recommendations

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

Public health action plan

- ATSDR will develop and disseminate reliable and easily accessible information concerning asbestos-related health issues for people who have been exposed to asbestos and for health care providers.
- ATSDR will publicize the findings of this health consultation in the community around the site. ATSDR will make the report accessible on the Internet and in the community.
- ATSDR will notify former workers for whom contact information is known and will provide them with exposure and health information about asbestos.
- ATSDR is researching and determining the feasibility of conducting additional worker and household contact follow-up activities.

Current or future workers and their household contacts (1983 to present/future)

After the Honolulu facility ceased vermiculite exfoliation in 1983, some residual asbestos remained inside the building and in onsite soil. Other businesses have leased the site since then. Employees on the site could have been exposed to residual asbestos during 1983–2001; however, information is insufficient to characterize these exposures. Areas of residual asbestos were remediated in November–December 2001; therefore, current (after December 2001) and future worker exposure pathways are considered eliminated and pose no public health hazard.

Recommendations

- Promote awareness of potential past asbestos exposure among employees that worked at the site from 1983 through December 2001.
- Encourage these workers to inform their primary care physician about their potential exposure to asbestos.

Public health action plan

- ATSDR will develop and disseminate reliable and easily accessible information concerning asbestos-related health issues for people who have been exposed to asbestos and for health care providers.
- ATSDR will publicize the findings of this health consultation in the community around the site. ATSDR will make the report accessible on the Internet and in the community.
- ATSDR will notify former on-site employees for whom contact information is known and will provide them with exposure and health information about asbestos.

Community members who lived near the facility (1954–1983)

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

Recommendations

- Promote awareness of potential past asbestos exposure among community members who lived near the facility during 1954–1983. Provide these people with easily accessible materials that will help them identify their own exposures.
- Encourage people who lived in the community in the past and feel they were exposed to asbestos to inform their primary care physician about their potential asbestos exposure.

Public health action plan

- ATSDR will develop reliable, easily accessible, and understandable information concerning asbestos-related health issues for people who may have been exposed to asbestos and for health care providers in the area.

- ATSDR will publicize the findings of this health consultation in the community around the site; ATSDR will make the report accessible on the Internet and in the community.

Community members who live near the site now (1983 to present)

The Honolulu facility no longer processes vermiculite at the site; they stopped processing vermiculite from Libby in 1983. Many of the community exposure pathways, such as ambient emissions and disturbing or playing on on-site waste piles, have been eliminated. Some areas of asbestos-contaminated soil at the site were excavated and removed in 2001; no residual asbestos is present at the site. These exposure pathways pose *no public health hazard* to the surrounding community members.

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

Recommendations

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

Public health action plan

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

Author, Technical Advisors

Author

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

Regional Representative

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

Technical Reviewers

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

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

References

1. US Environmental Protection Agency. Vermiculite exfoliation plant surveys: Arizona, California, and Nevada. Prepared for EPA Region 9 by Ecology and Environment, Inc.: EPA; July 25 2000.

2. US Environmental Protection Agency. Focused removal assessment report, Hawaii Staging and Lighting/Funtastic Party Rental & Supply. Prepared for EPA Region 9 by US Department of Transportation Volpe Center and CDM Federal Programs Corporation. San Francisco, CA: EPA Region 9; July 2001.

3. US Bureau of Mines. Minerals yearbook metals and minerals (except fuels) 1954: vermiculite. Washington DC: US Bureau of Mines (BOM); 1954.

4. US Bureau of Mines. Minerals yearbook area reports, domestic 1967: Hawaii. Washington DC: US Bureau of Mines (BOM); 1967.

5. US Bureau of Mines. Minerals yearbook area reports, domestic 1955: Hawaii. Washington DC: US Bureau of Mines (BOM); 1955.

6. Masa Fujioka & Associates. Asbestos remediation actions, 842-A Mapunapuna Street, Honolulu, Hawaii. Prepared for the Estate of Samuel Mills Damon. Aiea, Hawaii: Masa Fujioka & Associates; Jan 30, 2002.

7. US Environmental Protection Agency. Pollution report for the Hawaii Stage and Lighting site removal action, Honolulu, HI. San Francisco, CA: EPA Region 9; Apr 18, 2002.

8. Environmental Data Resources. Aerial photography print service for 842A Mapunapuna Street, Honolulu. HI. Historical aerial photographs from US Geological Survey (1974, 1976, 1978). Milford, CT: Environmental Data Resources, Inc.; 2004.

9. Bureau of the Census. Census 2000. US Department of Commerce. Available at: http://www.census.gov.

10. Western Regional Climate Center (Desert Research Institutue in cooperation with National Oceanic and Atmospheric Administration). Historical climate information. Desert Research Institute. Available at: http://www.wrcc.dri.edu/. Accessed Feb 15, 2005.

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

12. Atkinson GR, Rose D, Thomas K, Jones D, Chatfield EJ, Going JE. Collection, analysis and characterization of vermiculite samples for fiber content and asbestos contamination. Prepared for EPA Office of Pesticides and Toxic Substances, Field Studies Branch by

Midwest Research Institute. Washington DC: US Environmental Protection Agency; Sept 1982.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

35. US Environmental Protection Agency. Memorandum to P Peronard (On-Scene Coordinator, Libby Asbestos Site, EPA Region 8) from CP Weiss (Senior Toxicologist/Science Support Coordinator, Libby Asbestos Site, EPA Region 8) Amphibole mineral fibers in source materials in residential and commercial areas of

Libby pose an imminent and substantial endangerment to public health. Denver: EPA; December 20, 2001.

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

37. W.R. Grace & Company. Memorandum to JC York (President, Vermiculite of Hawaii) from AN Crawford (Vermiculite Development Manager, W.R. Grace & Company) concerning termination of licensing agreement with Vermiculite of Hawaii. US EPA database of W.R. Grace documents (S8020110481): EPA Region 8; October 18, 1984.

38. Anderson BA, Dearwent SM, Durant JT, Dyken JJ, Freed JA, Moore SM, et al. Exposure pathway evaluations for sites that processed asbestos-contaminated vermiculite. Int J Hyg Environ Health. April 8, 2005;208(1):55-65.

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

40. Agency for Toxic Substances and Disease Control. Health consultation: exposure assessment for Western Mineral Products, Minneapolis, Hennepin County, Minnesota. Prepared for ATSDR by Minnesota Department of Health. Atlanta: US Department of Health and Human Services; Oct 2003.

41. Agency for Toxic Substances and Disease Control. Health consultation: Western Minerals Products, Omaha, Douglas County, Nebraska. Atlanta: US Department of Health and Human Services; Oct 2004.

42. Agency for Toxic Substances and Disease Control. Health consultation: Former Zonolite Company/W.R. Grace exfoliating plant, Town of Brutus, Cayuga County, New York. Prepared for ATSDR by New York State Department of Health. Atlanta: US Department of Health and Human Services; Mar 2004.

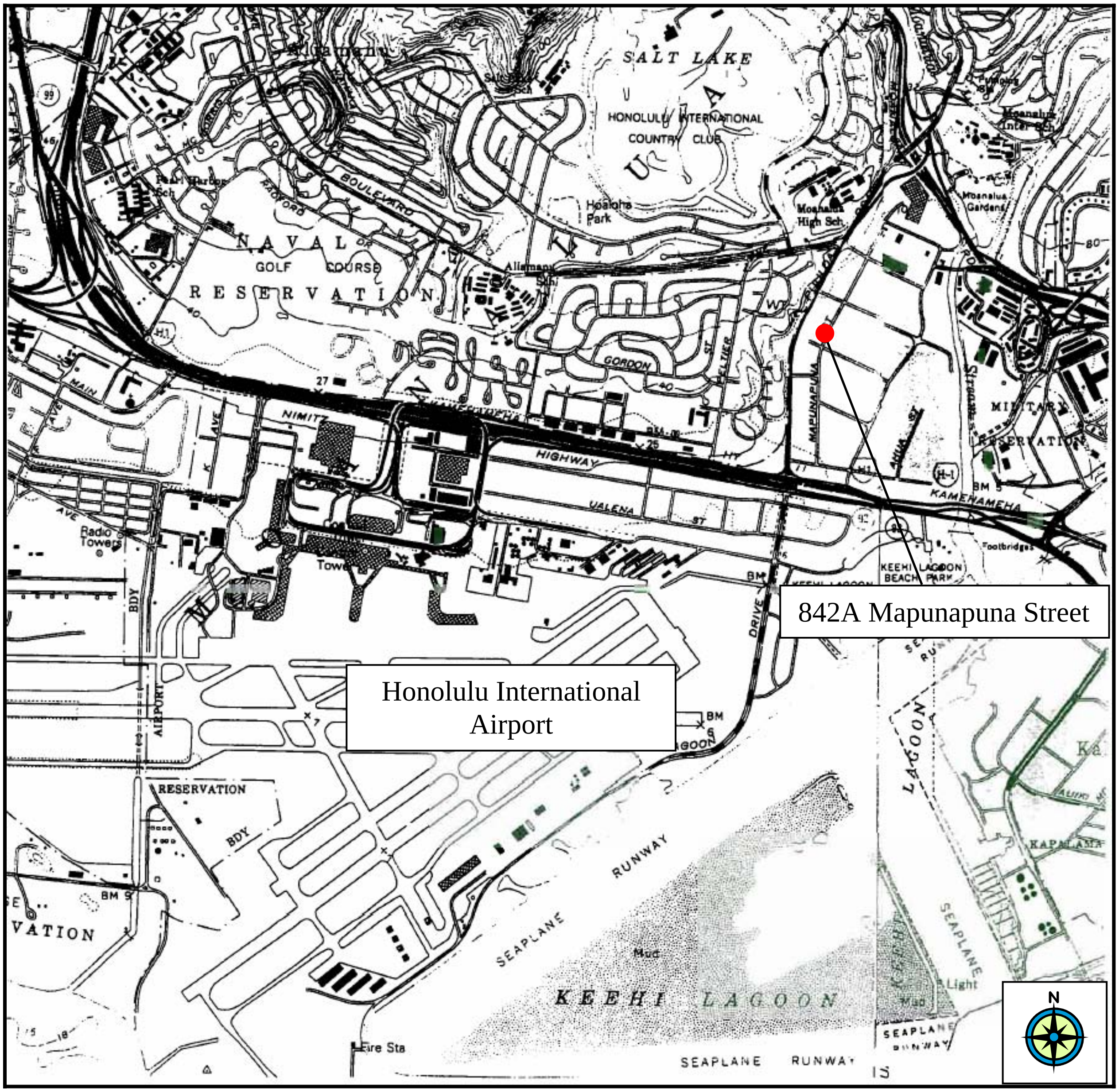
43. Anderson HA, Lilis R, Daum SM, Selikoff IJ. Asbestosis among household contacts of asbestos factory workers. Ann N Y Acad Sci. 1979;330:387-99.

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

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

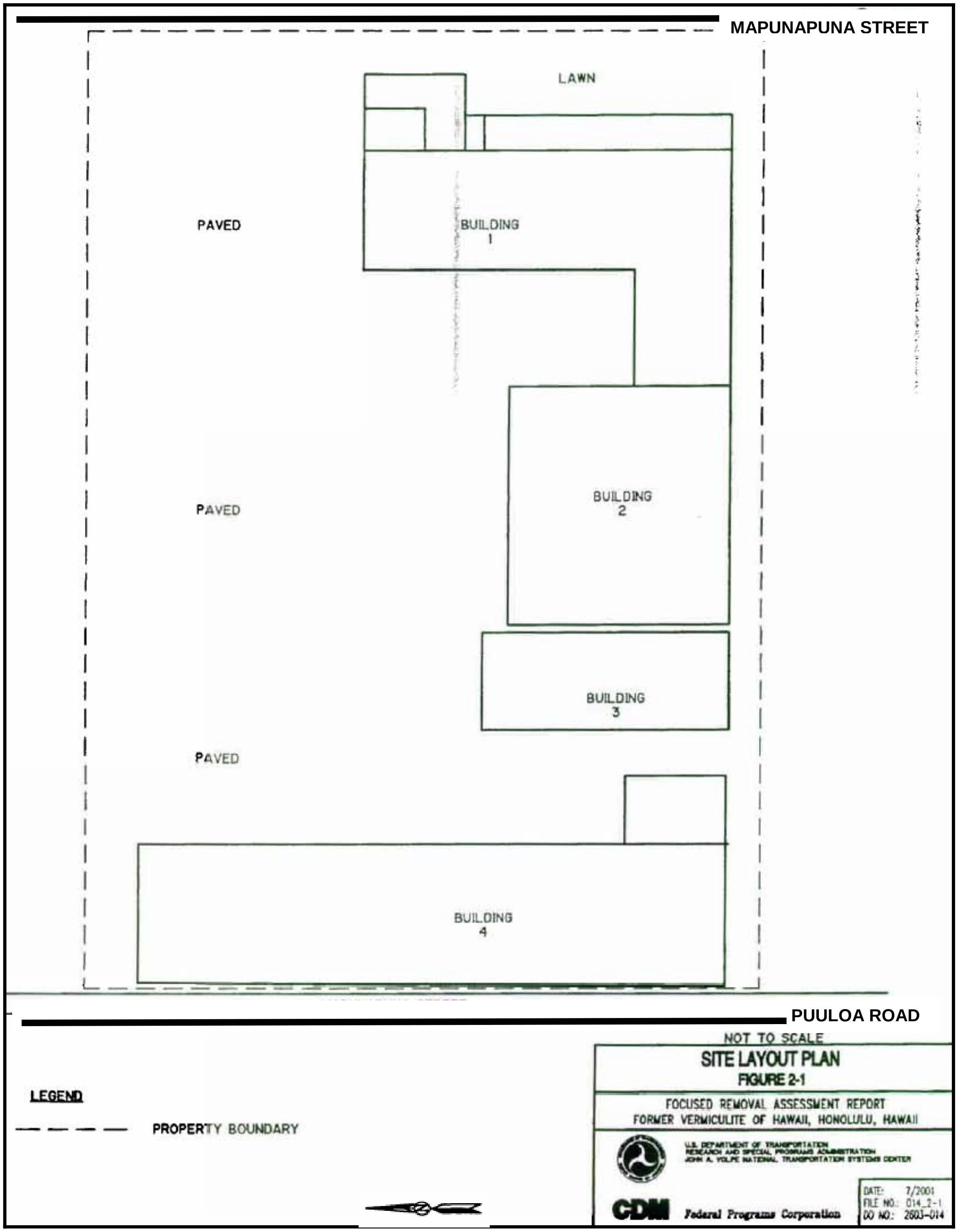
Figures

Figure 1. Site location map*



* Source: Historical topographic map report for 842A Mapunapuna Street, Honolulu, Hawaii. Historical U.S. Geological Survey 7.5' topographic maps for Honolulu and Pearl Harbor quadrangles (1983). Milford, Connecticut: Environmental Data Resources, Inc.; 2004.

Figure 2. Site layout*



* Source: U.S. Environmental Protection Agency. Focused removal assessment report, Hawaii Staging and Lighting/Funtastic Party Rental & Supply. Prepared for EPA Region 9 by U.S. Department of Transportation Volpe Center and CDM Federal Programs Corporation. EPA; July 2001. Revised to depict street locations.

Figure 3. 1990 US census data for the area surrounding the Honolulu site

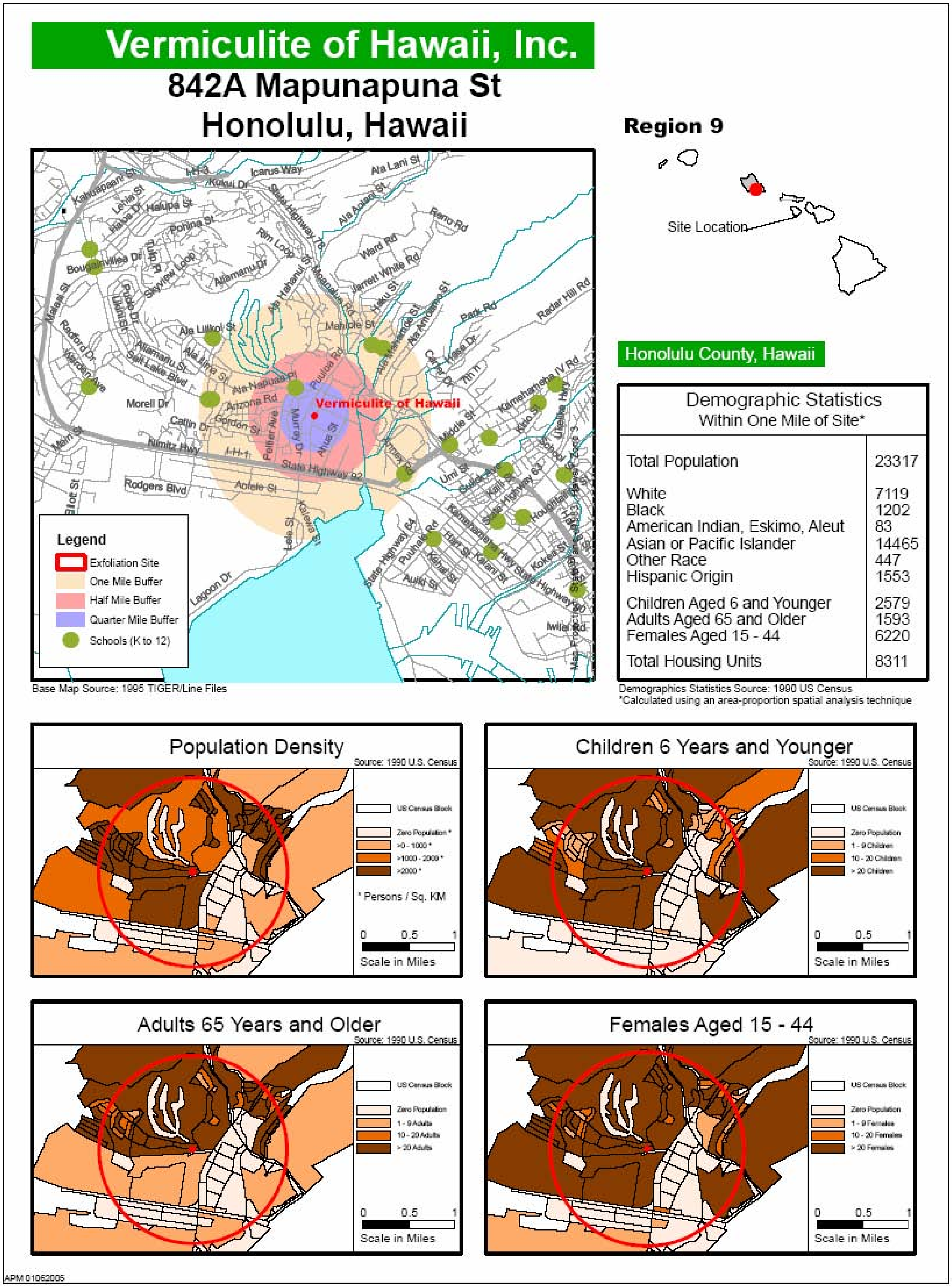


Figure 4. Meteorological data from the Honolulu International Airport

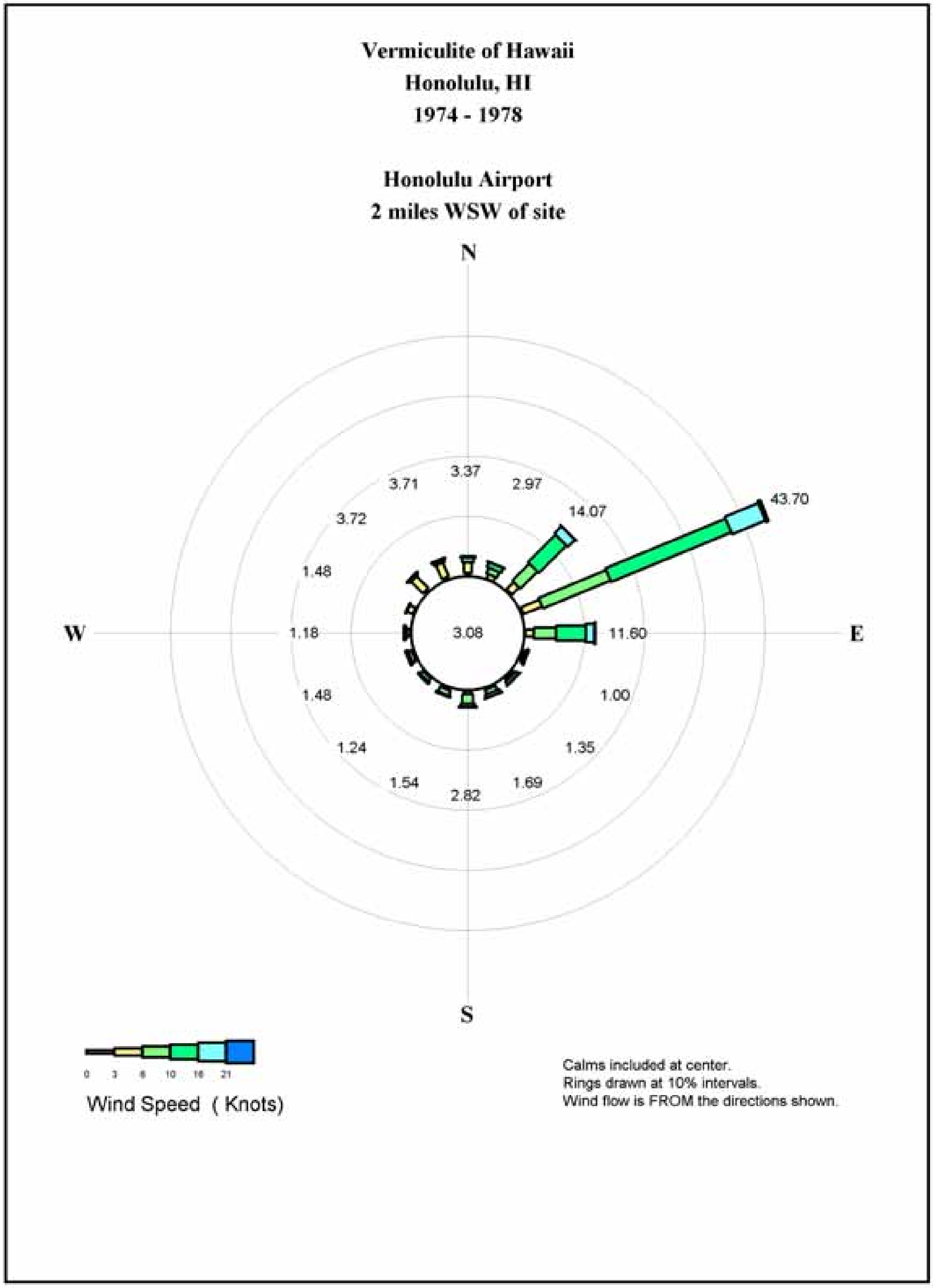


Figure 5. Vermiculite

Figure 6. Waste rock

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

Appendix A. Definitions

Exposure pathways

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

Public health hazard categories

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

No public health hazard

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

No apparent public health hazard

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

Indeterminate public health hazard

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

Public health hazard

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

Urgent public health hazard

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

Appendix B. Asbestos overview

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

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

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

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

Methods for Measuring Asbestos Content

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Current Standards, Regulations, and Recommendations for Asbestos

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

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

OSHA's permissible exposure limit (PEL) is 0.1 f/cc for asbestos fibers with lengths >5 µm and with an aspect ratio (length:width) >3:1, as determined by PCM [6]. This value represents a time-weighted average (TWA) exposure level based on 8 hours per day for a 40-hour work week. In addition, OSHA has defined an "excursion limit," which stipulates that no worker should be exposed in excess of 1 f/cc as averaged over a sampling period of 30 minutes [6]. Historically, the OSHA PEL has steadily decreased from an initial standard of 12 f/cc established in 1971. The PEL levels prior to 1983 were determined on the basis of empirical worker health observations, while the levels set from 1983 forward employed some form of quantitative risk assessment. ATSDR has used the current OSHA PEL of 0.1 f/cc as a reference point for evaluating asbestos inhalation exposure for past workers. ATSDR does not, however, support using the PEL for evaluating exposure for community members, because the PEL was developed as an occupational exposure for adult workers.

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

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

EPA has set a maximum contaminant level (MCL) for asbestos fibers in water of 7,000,000 fibers longer than 10 µm per liter, on the basis of an increased risk for 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's IRIS model calculated an inhalation unit risk for cancer (cancer slope factor) of 0.23 per f/cc of asbestos [3]. This value estimates additive risk for lung cancer and mesothelioma using a relative risk model for lung cancer and an absolute risk model for mesothelioma.

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

Appendix B References

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

2. Midwest Research Institute. Collection, analysis, and characterization of vermiculite samples for fiber content and asbestos contamination. Kansas City: US Environmental Protection Agency, Office of Pesticides and Toxic Substances; Sept 1982.

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

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

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

6. Occupational Safety and Health Administration. Federal Register 59:40964-41162, Aug 10, 1994 and 60:33973-34002, June 29, 1995.

7. Berman DW, Crump K. Methodology for conducting risk assessments at asbestos Superfund sites. Part 2: Technical background document (interim version). Prepared for the U.S. Environmental Protection Agency Region 9. San Francisco: February 15, 1999.

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

9. Weis CP (EPA). Memorandum to P. Peronard of U.S. Environmental Protection Agency, Amphibole mineral fibers in source materials in residential and commercial areas of Libby pose an imminent and substantial endangerment to public health. Denver: US Environmental Protection Agency; December 20, 2001.

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

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

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

13. Centers for Disease Control and Prevention. Online NIOSH pocket guide to chemical hazards. Accessed on July 16, 2002, at: http://www.cdc.gov/niosh/npg/npgd0000.html.

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

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

Appendix C. Exposure pathways for vermiculite processing facilities*

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

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