Evaluation of Employee Exposures to Libby Amphibole Asbestos During Forest Management Activities in the Kootenai National Forest

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a federal forest management agency. Employees were concerned about exposure to Libby amphibole during forest management activities and wildland fire suppression in the Kootenai National Forest near a former vermiculite mine in Libby, Montana. We visited the federal agency station in April 2012 and August 2012.

What We Did

- We looked at forest management and administrative work activities.
- We took personal air samples on employees for each activity they did and for the work shift.
- We took bulk samples of the duff (forest vegetation) and soil.
- We took wipe and vacuum samples from equipment and bench top surfaces in the hydrology lab.
- We looked at personal protective equipment use and talked with employees about their jobs and health and safety concerns.
- We measured temperature and relative humidity during all activities.

We evaluated employee concerns about exposure to Libby amphibole during forest management activities. Although Libby amphibole was detected on some air samples, employee exposures did not exceed occupational exposure limits for asbestos. We made recommendations on respiratory protection, exposure monitoring, and personal protective equipment.

What We Found

- Employee exposures to Libby amphibole in air were below occupational exposure limits.
- We detected no Libby amphibole in the bulk or surface samples.
- Managers and employees were aware that Libby amphibole was present in fire management unit 3, but less aware about the potential for exposure or needed precautions.
- Some employees wore respirators when working in or around areas surrounding fire management unit 3.
- After working in fire management unit 3, employees removed and discarded equipment and clothing, showered, and changed into street clothing.

What the Employer Can Do

- Create a respirator program for employees working in fire management unit 3.
- Start a program to periodically monitor employees' exposure to Libby amphibole. Do this for forest management and fire suppression activities.
- Evaluate exposure to silica during dusty activities.
- Train employees on good work practices to minimize dust.
- Limit how often employees enter fire management unit 3.
- Schedule dust generating work (e.g., soil and duff disturbance work) when the potential for dust generation is low, such as when it is raining or a snow cover is present.
- Analyze samples by electron microscopy in addition to current methods. This step will provide better information about whether Libby amphibole fibers are present.

What Employees Can Do

- Understand and follow all the protocols and procedures for working in fire management unit 3 and other areas.
- Notify your supervisor of any health or safety concerns.

Abbreviations

f/cc	Fibers/cubic centimeter
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
FMU3	Fire management unit 3
PAPR	Powered air-purifying respirator
PCM	Phase contrast microscopy
PEL	Permissible exposure limit
PPE	Personal protective equipment
REL	Recommended exposure limit
TEM	Transmission electron microscopy
TWA	Time-weighted average

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Introduction

The Health Hazard Evaluation Program received a request from managers of a federal forest management agency that serves the Kootenai National Forest in Montana. The request concerned employees' potential exposure to Libby amphibole during forest management and fire suppression activities in the area designated as fire management unit 3 (FMU3). The area is also known as operable unit 3 (OU3) by the United States Environmental Protection Agency (EPA). FMU3 surrounds a former vermiculite mine and areas impacted by the mine releases (Figure 1). FMU3 and other areas around the mine include approximately 32,000 acres and is an EPA National Priorities List Superfund site.

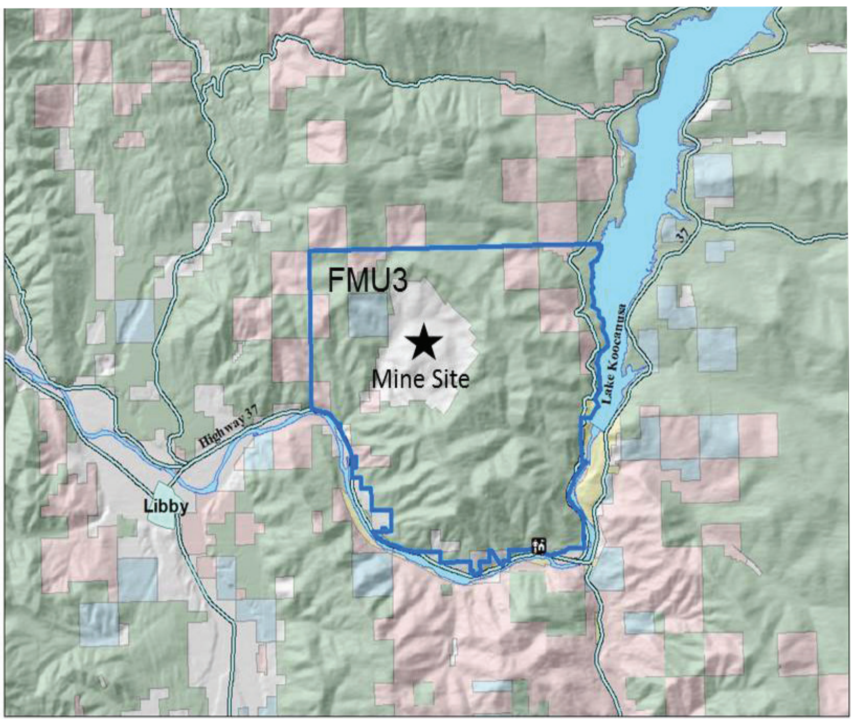


Figure 1. FMU3 and mine site. Map courtesy of U.S. Forest Service.

We discussed the concerns during an initial visit in April 2012. Following an opening meeting with federal agency managers, employees, and EPA representatives, we obtained information on personal protective equipment (PPE) use, administrative controls, and decontamination protocols for reducing potential Libby amphibole exposure. We observed work practices, equipment, and vehicles used for forest management in and around FMU3. We also inspected the hydrology laboratory because of employee concerns about the dust generated when processing stream bed samples. Using this information, we developed an exposure assessment sampling strategy for Libby amphibole. In August 2012, we visited the site again to evaluate employee exposures to Libby amphibole as the employees worked in forest management activities. We sent interim reports with initial findings and recommendations to the forest managers and employee representatives in April 2012 and September 2012.

Background

Libby, Montana Site History

In 1881, gold miners discovered vermiculite near Libby, Montana and in the 1920s the Zonolite Company began mining the vermiculite. In 1963, the W.R. Grace Company bought the Zonolite mining operations and operated the mine until it closed in 1990. While in operation, the Libby mine is thought to have produced 80% of the world's supply of vermiculite [EPA 2012]. In addition to vermiculite ore, asbestiform minerals, i.e., the fibrous minerals tremolite, winchite, and richterite, also were present. Together, these minerals are referred to as Libby amphibole asbestos (or Libby amphibole).

In response to local concern and news articles about asbestos-contaminated vermiculite, the EPA began an investigation of Libby amphibole in November 1999. The Libby asbestos site, including FMU3 and other operable units in and around Libby, was added to the EPA National Priorities List in October 2002 and declared a public health emergency in 2009 [EPA 2009, 2012]. This action was the first time EPA determined under the Comprehensive Environmental Response, Compensation, and Liability Act that conditions at a site constituted a public health emergency.

High incidences of asbestos related morbidity and mortality have been documented among former mine and mill employees in this area [Amandus and Wheeler 1987; Amandus et al. 1987]. Increased prevalences of asbestos related morbidity and mortality and radiographic pleural changes have been observed among community members and residents in this area [Peipins et al. 2003; Whitehouse 2004; Sullivan 2007]. In 2005, academic researchers determined that trees surrounding the former vermiculate mine in FMU3 were a reservoir for Libby amphibole [Ward et al. 2006]. This study and subsequent research indicated Libby amphibole was present in tree bark, forest duff, and soil [Hart et al. 2009; EPA 2011; Tetra Tech 2012]. In additional research, airborne asbestos fibers were detected in smoke from wood burning stoves and from other activities in the forested FMU3 area, such as firewood harvesting and wildland fire suppression tasks (e.g., fireline construction and mop-up) [Hart et al. 2007; Hart and Spear 2009; Hart et al. 2009; Ward et al. 2009]. The EPA has found Libby amphibole when conducting personal monitoring during activity-based sampling for a variety of activities [EPA 2011, 2013, 2014].

For the Libby area, the presence of Libby amphibole in FMU3 and surrounding operable units has not been fully characterized. No clear boundaries have been established regarding the extent of Libby amphibole contamination in nearby forested areas.

Canoe Gulch Ranger District

Approximately 32,000 acres within the FMU3 area are managed by the federal agency. The federal agency ranger district is responsible for managing federal lands inside FMU3 and in surrounding areas. A federal agency ranger station is located just outside the FMU3 boundary in the EPA-designated operable unit 4. Approximately 40 full-time, permanent federal employees are employed at the ranger station. In the summer, up to 100 additional seasonal employees may be hired. Work shifts are typically 8–10 hours per day. Most of the work done by ranger station employees involves land management activities, including civil engineering, trail and road maintenance, forest biology, fuels and timber management, hydrology, and wildland fire suppression. In winter months, the average work shifts are typically 8 hours, and work is done indoors and outdoors. In summer months, work shifts are typically 10 hours, with most work tasks being done outdoors. No research is done at the ranger station.

Federal forest wildland fire suppression operations and management activities in FMU3 have decreased since 2008–2009 when EPA declared the area a public health emergency and Libby amphibole contamination of tree bark, soil, and duff was identified. However, non-fire suppression activities such as trail maintenance and fuels management have occurred periodically in FMU3 since that time.

Methods

The purpose of our evaluation was to characterize employee dust exposures during activities believed to present a risk of exposure to Libby amphibole. Our evaluation included the following methods: (1) observing work activities and use of PPE and (2) collecting and analyzing the following samples for asbestos and Libby amphibole: full shift and activity-based personal air samples on employees; bulk samples of bark, duff, and soil; and wipe and vacuum samples from surfaces in the hydrology lab. We asked federal agency managers to help identify and prioritize the work activities in and around FMU3 based on the potential for dust generation, the number of employees involved, and the frequency and duration of the work. Federal agency managers were also interested in potential Libby amphibole exposures when employees drove in and out of the operational unit areas. We planned to evaluate potential Libby amphibole exposures during a prescribed wildland burn, but the burn was not done because of extreme fire conditions during our evaluation. The 10 work activities we evaluated are summarized in Table 1. These activities are typical for summer work.

Table 1. Work activities observed and monitored during the National Institute for Occupational Safety and Health (NIOSH) evaluation

Activity	Description
Civil engineering	One employee observed road grading and brush cutting on Alexander Creek Road, Tamarak Creek Road, and Bear Creek Road.
Fire cache fuel reduction and tool maintenance	Seven employees did fuel reduction activities at the fire cache outside the boundary of FMU3. Sawyers operated chainsaws to cut down small trees and brush. Swampers hauled the brush and trees for removal. Employees also moved supplies in the engine garage, cleaned coolers, and refurbished hand tools and chainsaws. This work was done indoors and outdoors.
Fireline construction	Seven employees constructed 0.6 miles of fireline, approximately 30 centimeters wide, southwest of the FMU3 boundary (Figure 2). Employees removed combustible material to create a 1–2 meter firebreak by cutting and removing trees and brush with a chainsaw, then removing the duff and roots using specialized fire-suppression hand tools (combination tool, Pulaski, and McLeod hoe).
Fuel reduction	Two sawyers used chainsaws to cut brush and small trees along a roadway, and five swampers collected and piled the cuttings.
Hydrology	Two employees processed dry river bed samples, including weighing, sieving, and performing various analyses inside the lab. One employee collected core samples from stream beds and analyzed them in the hydrology lab.
Lawn care and maintenance	One employee mowed, weeded, and raked around the ranger station.
Office work	Two employees did administrative activities inside the ranger station office buildings.
Road maintenance	One employee raked and graded gravel and dirt roads in FMU3 and on other federal lands.
Timber stand assessment	Four employees performed timber assessments outside the boundary of FMU3. Employees evaluated the commercial value and health of the forest and determined if a fuels reduction or commercial thinning project was needed (Figure 3).
Trail maintenance	Four employees cleared the trail of brush and logs on the Alexander trail inside FMU3 approximately 2 miles from the vermiculite mine (Figure 4).

Figure 2. Fireline construction. Photo by NIOSH.

Figure 3. Timber assessment and stand exam - tree boring in Jackson Creek area, outside of FMU3. Photo by NIOSH.

Figure 4. Trail maintenance – sawing and swamping, Alexander Creek trail, FMU3. Photo by NIOSH.

Air, Bulk, and Surface Sampling

We collected personal air samples for asbestos and other fibers on employees during the activities listed in Table 1. Sampling and analysis was according to NIOSH Method 7400 [NIOSH 2014]. We changed the sample filters as needed during the workday to prevent overloading and removed the filter cassettes and sampling pumps during lunch breaks and when employees underwent decontamination. Each employee wore two sampling devices so we could evaluate full shift and activity-specific exposures.

Because the field work took place in a forest environment, it was expected that the phase contrast microscopy (PCM) results would reveal a substantial portion of cellulose-containing material that met the morphological definition of a fiber. Additionally, because PCM does not distinguish between asbestos and non-asbestos fibers, or determine fiber mineralogy, we also analyzed the samples for Libby amphibole and other mineral fibers with transmission electron microscopy (TEM) according to NIOSH Method 7402 [NIOSH 2014]. For TEM analysis, we selected 27 personal air samples representing the 10 work activities and the 12 highest fiber counts as determined by PCM.

We collected bulk samples of soil, duff, and bark for asbestos analysis with polarized light microscopy according to NIOSH Method 9002 [NIOSH 2014]. Polarized light microscopy analysis of bulk samples is reliable only when more than 1% of the material is asbestos.

We collected surface wipe samples for asbestos with pre-moistened SKC, Inc. Ghost Wipes. We used a 10 centimeter by 10 centimeter template to outline the sample area, where possible. For small or irregularly shaped surfaces we estimated the sampled area. We wore a new pair of gloves to take each sample. The wipe samples were analyzed with TEM following the American Society for Testing and Materials D 6480-05 wipe sampling for settled asbestos protocol [ASTM 2010]. The filters from the suspension of each sample used for TEM examination were also analyzed by polarized light microscopy to ensure that asbestos materials that may have been poorly distributed on the filter were not missed in TEM analysis.

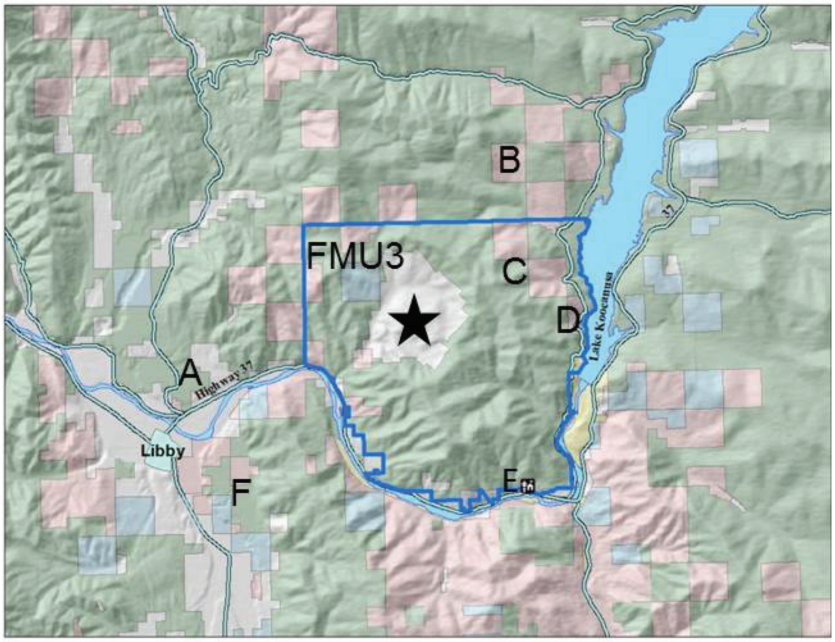
We collected surface vacuum samples in the hydrology laboratory for asbestos. These samples were collected by vacuuming a 10 centimeter by 10 centimeter area following American Society for Testing and Materials D 5755-03, with analysis by TEM [ASTM 2003].

Results and Discussion

Activities Monitored and Workplace Observations

Descriptions of the activities and number of employees monitored for each activity are provided in Table 2. Over the course of the evaluation, many of the same employees performed multiple activities. This work was done outdoors, with the exception of the time spent en route to the worksite in a government vehicle and returning to the ranger station, unless otherwise noted. Figure 5 provides a map of activity locations. All activities occurred within a 6.5-mile radius of the former vermiculite mine (Figure 5). Two of the activities, trail maintenance and fuels reduction, occurred within the FMU3 boundary (Figure 5).

Exposure monitoring was done during the summer. There was no precipitation during our visit. The meteorological conditions included temperatures (in degrees Fahrenheit) from the upper 40s (morning) to mid-90s (afternoon), percent relative humidity in the mid-teens (afternoon) to low-90s (morning), and wind speeds from 5–11 miles per hour. Morning dew was observed on vegetation during early morning activities, but no measured precipitation was reported. One wildland fire was reported in the region approximately 10 miles north of the FMU3 boundary, midway through our August visit; however, it did not interfere with our sampling.



★ = Mine site

A = Fire cache fuel reduction, administrative, and tool maintenance; hydrology: 6.5 miles from mine site

B = Timber assessment: 3.9 miles from mine site

C = Trail maintenance: 2.2 miles from mine site

D = Fuel reduction: 3.9 miles from mine site

E = Ranger station - lawn care and maintenance; office activities: 5.1 miles from mine site

F = Fireline construction: 6.3 miles from mine site

Figure 5. NIOSH sampling locations. Map courtesy of U.S. Forest Service.

Table 2. Work activity observations and PPE use

Activity	Observations and PPE use
Civil engineering	The employee did not wear specific PPE. Most of the work shift was spent in the vehicle driving on roads in and out of FMU3. The employee exited the vehicle multiple times during the day for 5–40 minutes to check on contractor activities.
Fire cache fuel reduction and tool maintenance	All employees wore wildland fire specific PPE (e.g., aramid fabric shirts and trousers [Nomex®], hardhats, hearing protection, safety glasses, and safety shoes). No respirators were worn. Because of extreme heat, employees worked on less strenuous activities in the afternoon after doing more strenuous work in the morning. Work occurred indoors and outdoors at the fire cache.
Fireline construction (Figure 2)	Most employees wore wildland fire specific PPE, but did not wear respirators. Some employees did not wear safety glasses.
Fuel reduction	All employees wore wildland fire specific PPE and full facepiece powered air purifying respirators or half-mask air purifying respirators with P100 particulate filters. All employees completed a three-stage wet decontamination process (Figure 6). The decontamination steps are (1) remove work clothing/gear, (2) proceed to the second stage water shower; and (3) proceed to the third stage to dress into street clothing.
Hydrology	Surfaces in the laboratory were visibly dusty. Employees did not work in the laboratory at the same time. Automated screening took place in a room with a closed door and a fan venting to the exterior of the building. It was likely that suspended dust was still present in the room air at re-entry. One employee wore a half-mask air purifying respirator with P100 particulate filters.
Lawn care and maintenance	The employee wore a long sleeve shirt, hearing protection, safety glasses, hard hat, and work boots during lawn mowing and other outdoor activities. With the exception of maintaining equipment in a shed, all work was done outdoors.
Office work	The majority of the work day was spent inside one or more office buildings, but the employees commonly walked between buildings. No specific PPE was worn.
Road maintenance	Most work was done while driving in a government vehicle. Vehicle windows were open when driving. The employee periodically exited the vehicle to work with hand tools. The employee wore leather gloves and a half-mask air purifying respirator with P100 particulate filters. The employee used a hose to rinse the vehicle after the work shift.
Timber stand assessment (Figure 3)	Teams of two employees hiked through the forest, randomly selected forest plots to evaluate, assessed the number and species of trees in a plot, measured tree height and width, bored into trees to determine age, and visually assessed tree health. Employees wore long sleeve shirts, boots, safety glasses, and hard hats.
Trail maintenance (Figure 4)	All four employees wore wildland fire specific PPE and full facepiece powered air purifying respirators or half-mask respirators with P100 particulate filters. All of the employees used the portable three-stage decontamination system.

Figure 6. Portable three-stage decontamination. Photo by NIOSH.

Personal Breathing Zone Sample Results

Tables A1–A8 (Appendix A) present individual full-shift and shorter-term activity-based personal air sample results by activity as determined by PCM analysis. Six out of 109 air samples analyzed by PCM exceeded the NIOSH recommended exposure limit (REL) and Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 0.1 fibers/cubic centimeter (f/cc), as an 8-hour time-weighted average (TWA) (See Appendix B for occupational exposure limits for asbestos and other fibers). These samples were all collected during the fireline construction activities (Table A4). An additional four samples from fireline construction had concentrations of 0.05–0.1 f/cc by PCM analysis. To determine if fibers detected by PCM were Libby amphibole, TEM analyses were performed on 27 samples. These samples included the 12 samples with the highest f/cc results by PCM and 15 samples chosen to represent all activities during the week.

Table A9 presents the calculated concentration based on PCM results for samples presented for TEM analysis together with the number and type of mineral fibers observed in 80 grid openings for each sample. Due to the low number of mineral fibers found, no attempt was made to adjust the PCM counts. Of the 27 samples evaluated, six contained mineral fibers, five contained richterite (one of the fibers that compose Libby amphibole), and one contained chrysotile (a serpentine form of asbestos). Of the five samples containing richterite, four were collected during fireline construction activities and one was collected during fuel reduction activities. The sample containing chrysotile was collected in the hydrology laboratory and was likely derived from sources other than the vermiculite mine. Chrysotile is a non-amphibole form of asbestos and is neither associated with the Libby mine nor present in Libby amphibole. The TEM results provide evidence that most fibers detected by PCM were not asbestos but were other fibers (e.g., cellulose-containing) that met the morphological fiber criteria defined in the PCM method.

On the basis of these results, we did not find that employee exposures to Libby amphibole exceeded occupational exposure limits (OELs) during various forest management activities in and around FMU3. Even though none of the exposures were above OELs, these results, may not be representative of potential exposures in other areas in or around FMU3, nor should they be extrapolated to wildland firefighting activities (wildland fire or prescribed burn). In addition, all activities where Libby amphibole fibers were identified were outside FMU3 with one exception (sawyer, Alexander Peak trail). This finding indicates employees working in areas outside of FMU3 may be exposed to Libby amphibole. Four of the five air samples containing Libby amphibole were collected during the dusty activity of fireline construction. Thus, appropriate precautions to protect employees during these types of activities should be implemented.

No asbestos fibers, including Libby amphibole, were detected on any of the surface wipe or surface vacuum samples collected in the hydrology laboratory. No asbestos fibers, including Libby amphibole, were detected in any of the bulk samples collected in the hydrology laboratory or when employees were doing forest management activities.

Our evaluation found non-asbestos material that met the definition of a fiber on samples analyzed by PCM. Because PCM is incapable of distinguishing between asbestos and non-asbestos fibers, erroneous conclusions could be drawn without this confirmatory analysis.

Occupational Safety and Health Programs

Wildland Fire Suppression

The federal agency had written health and safety programs and protocols for wildland fire suppression and response activities in FMU3 including a wildfire response guide and fire suppression job hazard analysis. Fire suppression protocols were designed to limit firefighters' exposure to Libby amphibole by first relying on aviation resources (e.g., water and retardant dropped from helicopters and air-tankers) to suppress the fire. If ground based firefighting personnel were necessary to supplement aviation resources, the agency identified and trained 15 non-seasonal employees who volunteered for wildfire suppression activities in this area. Mitigation measures for firefighters were identified and included avoiding smoke, minimizing the disturbance of duff, and minimizing use of chainsaws.

When working inside the FMU3 boundaries, the wildfire response guide indicates that federal agency personnel are required to wear a powered air purifying respirator (PAPR) and go through decontamination when doing suppression activities on the fireline or when exposed to smoke. Federal agency employees located outside of the FMU3 boundary, but who are supporting fire suppression activities in FMU3, have been approved to use half-mask respirators provided they are fit tested and complete an on-line medical screening form and the forest respiratory training program [Bradford 2012]. The job hazard analysis describes in detail the required wildland fire specific PPE, which includes the use of a PAPR, the PPE donning and doffing requirements, and decontamination of personnel and clothing. Since the wildland fire suppression guidelines were implemented, the one fire that required a response from the federal agency only required aviation resources for suppression.

Prior to any assignment associated with fire suppression in FMU3, firefighters must have a medical screening exam; be trained, medically cleared, and fit tested for a PAPR; complete a review of the respiratory protection plan, the job hazard analysis, and wildfire response guide; and complete a fire suppression drill and equipment checklist. In 2011, a medical monitoring program was implemented for the 15 employees who would conduct fire suppression activities in FMU3. It consists of a baseline medical examination as described in the OSHA asbestos standard, 29 CFR 1910.1001(l) Medical Surveillance.

The wildfire response guide indicates that ambient air sampling would be conducted during a wildfire to characterize the potential exposure to Libby amphibole from smoke. Because of the potential for ground disturbing activities and exposure to smoke, the federal agency should develop an exposure assessment strategy for firefighting personnel during wildland fires and prescribed burns. As wildland fires are unpredictable, considerable pre-planning is needed to ensure adequate preparation for sampling in the event of a fire.

Forest Management Activities

Since 2008, forest management activities (e.g., road and trail maintenance) have been significantly restricted in FMU3. The federal agency had no written protocols for non-wildland fire activities in FMU3; however, a supervisor reviews and approves all proposed activities in this area on the basis of need, duration, and time of year. The federal agency attempts to schedule work in FMU3 during environmental conditions that minimize dust exposures (e.g., when it is raining, or there is at least a 6-inch snow cover). Supervisors review activities and conditions in FMU3 and make recommendations on entry requirements, PPE, and work protocols/practices.

Although there was no written program for non-wildland fire activities, federal agency managers indicated they had a respiratory protection program and decontamination protocols for all work inside FMU3. Full facepiece PAPRs or half-mask air purifying respirators with P100 filters were required. All personnel we monitored in FMU3 wore respiratory protection. It was our understanding that the federal agency would use results from our evaluation to update and modify the respiratory protection program as appropriate. Given that our evaluation occurred over a limited period of time, additional monitoring under different conditions and activities is recommended to assist in determining whether respirator use should remain as currently defined, be changed (i.e., downgrade or upgrade the level of protection), or be discontinued. Additionally, although characterizing silica exposures was not part of this evaluation, the federal agency should evaluate silica exposures during those forest management activities having the potential to create a dusty environment, such as fireline construction. Ultimately, reducing dust exposures and limiting work in and around FMU3 is a reasonable risk-based strategy to reduce potential occupational exposures to Libby amphibole and silica.

All employees doing forest management activities in FMU3 were required to undergo decontamination upon completion of work and dispose of used equipment and PPE. The ranger station obtained a three-stage mobile decontamination unit (described in Table 2 and shown in Figure 6) and trained employees on how to deploy and use this unit. Only federal agency vehicles are used for work inside FMU3. During our visit the only vehicle we observed being washed was the road maintenance vehicle after the work shift. Washing the vehicles after traveling in FMU3 or on dusty roads would help in removing potential asbestos-containing dust and decrease the potential for secondary exposure. Frequent cleaning of the vehicle interior with a vacuum equipped with a high efficiency particulate air filter will also help decrease secondary exposures.

Wildland fire fighters are at increased risk of heat-related illness because of the metabolic work requirements of the job, the hot environmental conditions they work in, and the potential for long work hours. The use of additional PPE (e.g., respirators) to reduce potential exposures to Libby amphibole may create an additional physiological burden on the worker and may increase the likelihood of heat-related illness, especially during summer months.

Conclusions

Although Libby amphibole was found in some personal air samples, all concentrations we measured during various forest management activities in areas surrounding the former vermiculite mine were below OELs. No asbestos was identified in any of the bulk or surface samples we collected. Although our evaluation identified no overexposures to Libby amphibole, reducing dust generation and limiting the number of employees doing dust-generating activities is recommended.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the federal agency at the ranger station to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the ranger station.

These recommendations apply to all activities in all areas where forest management activities occur, and are good work practices that should be followed whenever dust exposure can occur, regardless of the presence or absence of Libby amphibole. These recommendations are consistent with the Agency for Toxic Substances and Disease Registry recommendations for employees in areas where asbestos may be present.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and PPE may be needed.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

Minimizing Dust Exposures

1. Limit how often employees enter FMU3.
2. Schedule dust generating activities (e.g. soil and duff disturbance work) when the potential for dust generation is low (rain/wet conditions, snow).
3. Use wet methods, where possible, to reduce dust generation. As is commonly done at construction and other outdoor work sites, use water trucks for dust suppression.
4. Wet wash equipment and vehicle exteriors at the end of the day/shift, and clean vehicle interiors frequently using a vacuum equipped with a high efficiency particulate air filter and wet wiping methods.
5. Ensure employees are informed of the need to use dust control methods during any work and that they are trained on dust control techniques. Inform contractors about potential exposures to Libby amphibole and procedures for reducing dust generation.
6. Prohibit dry sweeping, the use of leaf blowers, and the use of compressed air for cleaning clothing or other dusty materials and equipment.
7. Train ranger station employees about the hazards of Libby amphibole, areas where

Libby amphibole contamination is known or suspected, what is known and not known about exposure and health effects, actions to reduce their potential for exposure, scheduling work in FMU3, PPE use, and cleaning and decontamination, at a minimum. Update employees as new information is received.

8. Establish protocols for vehicle use on dirt/gravel roads (e.g., drive slowly, have vents closed, and keep windows closed).
9. Instruct employees to change into clean clothing before leaving the worksite or returning to their residence when they have been working in dusty areas. Work clothing should be cleaned according to the requirements of the OSHA asbestos standard, 29 CFR 1910.1001.
10. Instruct employees to move away from dusty work areas for breaks and wash their hands and face before eating, drinking, or smoking. Ensure that employees have clean water for this purpose.
11. Limit bystander exposure by preventing visitors and coworkers from standing in work areas where dust is generated.

Monitoring

1. Establish a program to periodically monitor exposure to Libby amphibole among federal agency employees. This program should include evaluating activities in and around FMU3 and during different climatic conditions. Further characterization of work activities, especially those that create dust, will provide additional data and help inform decisions about work practices and PPE.
2. Use TEM per NIOSH Method 7402 for all analyses to augment and confirm the results of any samples analyzed using the traditional PCM method, NIOSH Method 7400.
3. Characterize firefighter exposure to Libby amphibole during fire suppression activities (wildland fires and prescribed burns). As wildland fires are unpredictable, considerable pre-planning is needed to ensure adequate preparation for sampling in the event of a fire.
4. Evaluate employee exposure to silica during forest management activities that generate dust.

Personal Protective Equipment

PPE is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The right PPE must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. PPE should not be the sole method for controlling hazardous exposures. Rather, PPE should be used until effective engineering and administrative controls are in place.

1. Develop a written respiratory protection program to identify the job activities, type of respirator, and locations where respirator use is required. Respiratory hazards should be evaluated for job activities where respiratory protection is currently required to

ensure that the respirators being used are necessary and appropriate.

   a. If respirators are deemed necessary, the respiratory protection program must identify the type of respirator required for those activities.

   b. Ensure that all requirements in the OSHA respiratory protection standard [29 CFR 1910.134] are met (e.g., training, fit testing, medical clearance, respirator cleaning and storage).

2. Provide a copy of Appendix D of the OSHA respiratory protection standard [29 CFR 1910.134] to employees to meet the OSHA requirements for voluntary respirator use, if the federal agency allows voluntary respirator use (after a determination is made that respiratory protection is not required).

   a. Ensure that any employee using a respirator of higher protection than a filtering facepiece respirator is medically fit to use that respirator, and that the respirator is cleaned, stored, and maintained so that its use does not present a health hazard to the user.

   b. Job activities where employees voluntarily wear respirators should be noted in the written respiratory protection program.

   c. Encourage employees who voluntarily wear respirators to follow all aspects of proper respirator use including being clean shaven when using the respirator to ensure a good seal.

3. Consider how additional PPE may increase the physiological burden on the worker in this environment. Heat-related illness recommendations for wildland fire fighters can be found at http://www.fs.fed.us/eng/pubs/pdfpubs/pdf10512316/pdf10512316dpi300.pdf and http://www.cdc.gov/niosh/fire/reports/face201117.html.

Appendix A: Tables

Table A1. Personal air samples collected during sawing and clearing activities at the Alexander trail Head on August 13, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full shift sampling†					
Swamper 1	135	0958–1701¶	792	—	0.037
Swamper 2	144	1000–1700¶	777	—	0.027
Swamper 3	129	1008–1659¶	740	—	0.021
Swamper 4	123	1009–1700¶	729	—	0.043
Sawyer 1	86	0835–1236	471	0.044	0.041
	137	1312–1647¶	420	0.037	
Sawyer 2	122	0821–1236	506	0.046	0.033
	88	1338–1631¶	341	0.015	
Activity-specific sampling§					
Swamper 1	134‡	1130–1528	724	0.048	—
Swamper 2	131	1132–1527	714	0.035	—
Swamper 3	138	1118–1528	756	0.035	—
Swamper 4	132	1119–1520	736	0.037	—
Sawyer 1	145‡	0914–1234	690	0.084	—
Sawyer 2	127‡	0928–1236	566	0.075	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as described in Tables 1 and 2

¶Employee went through decontamination; pump removed for approximately 20 minutes

Table A2. Personal air samples collected during sawing and clearing activities at the fire cache on August 16, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Swamper 1	82	0813–1247	507	0.031	0.026
	157	1343–1603	421	0.018	
Swamper 2	92	0814–1245	530	0.0068	0.011
	156	1341–1601	424	0.020	
Swamper 3	1	0817–1249	529	0.021	0.019
	142	1345–1602	404	0.016	
Sawyer 1	80	0804–1250	551	0.0087	0.013
	158	1347–1603	409	0.021	
Sawyer 2	72	0810–1248	534	0.011	0.010
	161	1346–1603	418	0.0075	
Sawyer 3	146	0809–1248	552	0.011	0.013
	160	1344–1602	421	0.018	
Sawyer 4	136	0810–1246	550	0.019	0.021
	159	1342–1602	275	0.024	
Activity-specific sampling§					
Swamper 1	43	0940–1247	562	0.018	—
	157	1343–1603	421	0.018	
Swamper 2	65	0936–1245	572	0.010	—
	156	1341–1601	424	0.020	
Swamper 3	17‡	0938–1249	563	0.013	—
	142	1345–1602	404	0.016	
Sawyer 1	103‡	0934–1250	589	0.018	—
	15	1347–1603	409	0.021	
Sawyer 2	113	0933–1248	595	0.013	—
	161	1346–1603	418	0.0075	
Sawyer 3	91	0932–1248	598	0.014	—
	160	1344–1602	421	0.018	
Sawyer 4	119	0930–1246	595	0.013	—
	159	1342–1602	275	0.024	

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

Table A3. Personal air samples collected during sample analysis activities in the hydrology laboratory and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Laboratorian 1 – 8/13/13	126‡	0723–1153	536	0.010¶	—
Laboratorian 2 – 8/16/13	41	0746–0911	168	0.033	—
	33	0911–1010	116	0.025	
	63	1010–1722	852	Overloaded	
Activity-specific sampling§					
Laboratorian 1 – 8/13/13	110	0755–1152	720	0.007	—
Laboratorian 2 – 8/16/13	20	0746–0912	262	0.027	—
	58	0912–1010	177	0.035	
	50‡	1010–1204	347	0.017	
NIOSH observer	25	0840–0916	72	0.031	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

¶Employee left the hydrology laboratory after lunch. Full-shift sampling was not done.

Table A4. Personal air samples collected during fireline construction activities on August 14, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Employee 1	61‡ 133	0810–1207 1248–1649	474 729	0.13 0.0082	0.069
Employee 2	45‡ 105	0810–1205 1249–1647	468 728	0.094 0.0069	0.050
Employee 3	81 117	0825–1205 1250–1646	424 728	0.026 0.0089	0.017
Employee 4	68‡ 107	0829–1207 1251–1646	415 722	0.051 0.013	0.031
Employee 5	89‡ 101	0825–1208 1252–1647	432 707	0.10 0.013	0.055
Employee 6	24‡ 116	0829–1206 1253–1648	413 712	0.11 0.0053	0.056
Employee 7	39‡ 102	0839–1205 1253–1648	398 712	0.16 0.0088	0.079
Activity-specific sampling§					
Employee 1	125‡ 133	0918–1207 1248–1649	511 729	0.17 0.0082	—
Employee 2	27 105	0925–1205 1249–1647	489 728	Overloaded 0.0069	—
Employee 3	30 117	925–1204 1250–1646	491 728	0.026 0.089	—
Employee 4	51‡ 107	0931–1207 1251–1646	480 722	0.058 0.013	—
Employee 5	74‡ 101	0929–1208 1252–1647	478 707	0.081 0.013	—
Employee 6	77 116	0930–1206 1253–1648	479 712	Overloaded 0.0053	—
Employee 7	78‡ 102	0928–1203 1253–1648	469 712	0.14 0.0088	—
NIOSH Observer	94	1003–1218	412	0.033	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

Table A5. Personal air samples collected during various activities at the ranger station on August 14, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Office employee, technical services building	76	0733–1545	958	0.016	0.016
Maintenance, facilities and lawn care	143 66	0737–0956 0956–1103	279 134	0.022 0.036	0.027
Office employee, main building	139	0745–1147¶ 1317–1612	817	0.007	0.007
Activity-specific sampling§					
Office employee, technical services building	54	0733–1545	1500	0.009	—
Maintenance, facilities and lawn care	118 97	0737–0956 0956–1103	421 203	0.015 0.025	—
Office employee, main building	69	0745–1612	1543	0.004	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

¶Pump fault at 1147. Missing approximately 1.5 hours.

Table A6. Personal air samples collected during trail maintenance activities on the Alexander Peak trail on August 14, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Swamper 1	140	0739–1244	601	0.0092	0.010
	9	1244–1659¶	473	0.012	
Sawyer 1	2	0737–1243	607	0.0071	0.009
	15	1243–1608¶	371	0.012	
Swamper 2	6	0738–1246	596	0.019	0.016
	40	1246–1659¶	364	0.011	
Sawyer 2	104	0739–1241	598	0.017	0.022
	52	1241–1609¶	343	0.031	
Activity-specific sampling§					
Swamper 1	121	0940–1244	561	0.013	—
	26	1244–1524	488	0.014	
Sawyer 1	128	0940–1243	553	0.014	—
	49	1243–1525	490	0.011	
Swamper 2	148‡	0940–1246	563	0.016	—
	16	1246–1525	481	0.014	
Sawyer 2	34‡	0920–1241	610	0.019	—
	31‡	1241–1521	485	0.027	

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

¶Employee went through decontamination; pump removed for approximately 20 minutes

Table A7. Personal air samples collected during timber stand assessments in Jackson Creek and South Fork Junction on August 15, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Timber supervisor	37	0800–1542	885	0.098	0.098
Sr. fire fighter	112	0801–1541	888	0.018	0.018
Forestry technician 1	100 79	0803–1340 1341–1706	659 400	0.015 0.019	0.017
Forestry technician 2	62‡ 95‡	0843–1342 1342–1707	585 396	0.025 0.033	0.028
NIOSH observer	18 83	0810–1343 1344–1708	662 406	0.015 0.010	0.013
Activity-specific sampling§					
Timber supervisor¶	38‡	0844–1118	476	0.026	—
Sr. fire fighter	32 73	0845–1117 1212–1454	458 488	0.0089 0.011	—
Forestry technician 1	21 109	0845–1117 1223–1627	467 749	0.023 0.014	—
Forestry technician 2	84‡ 106‡	0845–1117 1221–1625	470 754	0.026 0.017	—
NIOSH observer	35	0847–1118 1227–1628	1196	0.0064	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

¶Air sample collected on this employee in the afternoon was lost. Morning sample result is provided.

Table A8. Personal air samples collected during other activities on August 15 and 16, 2012, and analyzed for asbestos with phase contrast microscopy

Job/Activity	Sample number	Sample time (military)	Sample volume (liters)	Sample concentration (f/cc)	Full shift TWA (f/cc)*
Full-shift sampling†					
Civil engineering technician, observe road grading and brush cutting on Alexander Creek Road, Tamarak Creek Road, and Bear Creek Road – August 15, 2012	70‡	0800–1536	889	0.023	0.023
Road raking and maintenance – August 16, 2012	93	0742–1552	955	0.021	0.021
Activity-specific sampling§					
Road raking and maintenance	48‡	0927–1420	898	0.011	—

*The NIOSH REL and OSHA PEL for asbestos, including Libby amphibole, is 0.1 f/cc

†Full-shift sampling, includes driving time, activities conducted, other ancillary (e.g., office) work

‡Sample also analyzed by TEM (Table A9)

§Activity-specific sampling for the activity as listed in Tables 1 and 2

Table A9. Personal air samples analyzed for asbestos using transmission electron microscopy

Job/Activity	Sample number	PCM concentration (f/cc)	Number and type of fiber detected by TEM*
Fuel reduction at the Alexander trail			
Swamper 1	134	0.048	0
Sawyer 1	145	0.084	0
Sawyer 2	127	0.075	0
Trail maintenance on Alexander trail			
Swamper 2	148	0.016	0
Sawyer 2	34	0.019	2 (richterite)
Sawyer 2	31	0.027	0
Fire cache fuel reduction and cleanup			
Sawyer 1	103	0.018	0
Swamper 3	17	0.013	1 (richterite)
Hydrology			
Laboratorian 1	126	0.010	0
Laboratorian 2	50	0.017	1 (chrysotile)
Fireline construction			
Employee 1	61	0.13	1.5 (richterite)
Employee 1	125	0.17	0
Employee 2	45	0.094	1 (richterite)
Employee 4	68	0.051	1 (richterite)
Employee 4	51	0.058	0
Employee 5	89	0.10	0
Employee 5	74	0.081	0
Employee 6	24	0.11	0
Employee 7	39	0.16	0
Employee 7	78	0.14	0
Timber stand assessment			
Timber supervisor	38	0.026	0
Forestry technician 2	62	0.025	0
Forestry technician 2	95	0.033	0
Forestry technician 2	84	0.026	0
Forestry technician 2	106	0.017	0
Other job/activities			
Civil engineering technician	70	0.023	0
Road maintenance	48	0.011	0

*The number and type of mineral fibers, including asbestos, confirmed by TEM on that sample

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limit or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the threshold limit values (TLVs), which are recommended by the American Conference of Governmental Industrial Hygienists, a professional organization, and the workplace environmental exposure levels, which are recommended by the American Industrial Hygiene Association, another professional organization. The threshold limit values and workplace environmental exposure levels are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. Threshold limit values are considered voluntary exposure

guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2014]. Workplace environmental exposure levels have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2014].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) PPE (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Asbestos

Asbestos is a commercial name, not a mineralogical definition, given to a group of six different fibrous minerals (amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite, and anthophyllite) that occur naturally in the environment. One of these, chrysotile, belongs to the serpentine family of minerals, while all of the others belong to the amphibole family. These minerals possess high tensile strength, flexibility, resistance to chemical, biological, and thermal degradation, and electrical resistance. Because of these properties, asbestos has been mined for use in a wide range of manufactured products, mostly in building materials, friction products, and heat-resistant fabrics. Chrysotile, also known as white asbestos, is the predominant commercial form of asbestos; amphiboles are considered of minor commercial importance. Historically, chrysotile accounted for more than 90% of the world's mined asbestos; it presently accounts for over 99% [Ross and Virta 2001; USGS 2008]. Chrysotile asbestos has been used in a number of applications in the United States, including thermal piping and industrial oven insulation, floor tile, vehicle brake pads, and in building material such as soffits. More information about asbestos is available at the NIOSH asbestos topic page http://www.cdc.gov/niosh/topics/asbestos/.

The current OSHA occupational 8-hour TWA exposure limit for airborne asbestos, including Libby amphibole, as determined by PCM is 0.1 f/cc for fibers greater than 5 micrometers in length and an aspect ratio (length to width) greater than or equal to 3:1 [29 CFR 1910.1001]. OSHA has also established an excursion limit that requires the employer to ensure that no employee is exposed to an airborne concentration of asbestos in excess of 1.0 f/cc as averaged over a sampling period of 30 minutes. Exposure limits or risk criteria for bulk or surface samples for asbestos have not been established. OSHA's definition of asbestos applies to chrysotile, amosite, crocidolite, tremolite asbestos, anthophyllite asbestos, actinolite asbestos, and any of these minerals that have been chemically treated and/or altered [29 CFR 1910.1001]. The OSHA definition of asbestos-containing material is any material containing more than 1% asbestos.

In 1990, NIOSH reviewed the available information on elongate mineral particles and concerns about potential health risks associated with employee exposures to the analogs of the asbestos minerals [NIOSH 1990a,b]. These analogs occur in a different mineral "habit" and are often referred to as cleavage fragments. PCM, the analytical method routinely used for characterizing airborne exposures, is incapable of differentiating these nonasbestiform analogs from asbestos fibers on the basis of physical appearance. To address these concerns and ensure that employees are protected, NIOSH defined "airborne asbestos fibers" to encompass not only fibers from the six asbestos minerals (chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos and actinolite asbestos) but also elongate mineral particles from their nonasbestiform analogs as a precautionary measure. NIOSH retained the use of PCM for measuring airborne fiber concentrations and counting those elongate mineral particles having an aspect ratio of 3:1 or greater and a length greater than 5 µm. The REL (0.1 f/cc) was set at the limit of quantification for the PCM analytical method for a 400-liter sample, but risk estimates indicated that exposure at 0.1 f/cc throughout a working lifetime would be associated with a residual risk for lung cancer. No risk-free level of exposure to airborne asbestos fibers has been established [NIOSH 1976, 1984, 2011]. More information on asbestos from NIOSH can be found at http://www.cdc.gov/niosh/docs/2011-159/.

Libby amphibole is a complex mixture of amphibole fibers found in the rocks and ore of Zonolite Mountain, 6 miles northeast of Libby, Montana (Figure 1). The mixture primarily includes tremolite, winchite, and richterite fibers with trace amounts of other minerals. These fibers exhibit a complete range of morphologies from prismatic crystals to asbestiform fibers [Meeker et al. 2003]. Zonolite Mountain contains a large vermiculite deposit that has been mined since the early 1920s for various commercial uses. Vermiculite miners, mill employees, and those working in the processing plants were exposed to these amphibole fibers, which remain within vermiculite ore and product. As amphibole asbestos is present in the geological deposit from which the vermiculite ore was being mined, employees were exposed to asbestos fibers during various activities such as extracting ore from the mine, transporting ore and waste rock, milling operations and shipping the final product [Meeker et al. 2003].

Inhalation exposure to asbestos can result in a scarring disease of the lung known as asbestosis, inflammation of the chest cavity (pleuritis) with or without fluid build-up, lung cancer, and another type of cancer known as malignant mesothelioma. The risk of these diseases, which can be disabling or fatal, generally increases with intensity and duration of exposure. The risk of lung cancer from inhaling asbestos fibers is also increased in smokers. Most people who get asbestos-related diseases have been exposed to high levels of asbestos for a long time. Most asbestos-related diseases rarely occur until at least 15 years after first exposure to asbestos. All forms of asbestos are hazardous, and all can cause cancer, but amphibole forms of asbestos are considered to be somewhat more hazardous to health than chrysotile [ATSDR 2001]. Asbestos fibers have no detectable odor or taste and fibers associated with these health risks are too small to be seen with the naked eye. A summary of asbestos-related diseases are listed below:

- Asbestosis – a serious, progressive, long-term disease of the lungs. It is caused by inhaling asbestos fibers that irritate lung tissues and cause the tissues to scar. The scarring makes it hard for oxygen to get into the blood.
- Lung cancer – people who mine, mill or manufacture asbestos, and those who use asbestos, and products containing asbestos, are more likely than the general population to develop lung cancer, as well as other cancers of the respiratory tract, including tracheal, laryngeal and bronchial cancers.
- Mesothelioma – a rare form of cancer that is found in the thin membrane lining (pleura) of the lung, chest, abdomen, and heart. The vast majority of cases are linked to asbestos exposure.

Exposure may also occur through ingesting (swallowing) asbestos, especially where airborne asbestos may deposit in the nose and mouth. Although some gastrointestinal cancers have been reported in asbestos-exposed employees, the evidence is considered suggestive, but not sufficient, to link asbestos exposure to those cancers [IOM 2006].

Exposure to Libby amphibole results in the same types of adverse health effects as are seen with exposure to other asbestos fibers. Mortality and morbidity studies on the mine and mill workers from Libby have reported adverse health effects in these employees including lung cancer, mesothelioma, nonmalignant respiratory disease, asbestosis, pleural anomalies, interstitial fibrosis, and altered lung function epidemiologic studies of workers exposed to Libby amphibole asbestos fibers indicate increased lung cancer and mesothelioma, as well as asbestosis and other nonmalignant respiratory diseases [Amandus and Wheeler 1987; Amandus et al. 1987; Peipins et al. 2003; Sullivan 2007; Larson et al. 2010].

Asbestos minerals are widespread in the environment. They may occur in large natural deposits, or as contaminants in other minerals. Low levels of asbestos can be detected in almost any air sample. The results of numerous measurements indicate that average concentrations of asbestos in ambient outdoor air are within the range of 10^{-8} to 10^{-4} PCM f/cc; levels in urban areas may be an order of magnitude higher than those in rural areas [ATSDR 2001]. In indoor air, the concentration of asbestos depends on whether asbestos was used for insulation, ceiling or floor tiles, or for other purposes, and whether these asbestos-containing materials are in good condition or are deteriorated and easily crumbled. Concentrations measured in homes, schools and other buildings that contain asbestos range from about 0.00003–0.006 f/cc. Indoor air concentrations of asbestos ranged from approximately 10^{-5} to 10^{-4} f/cc in a study of air concentrations measured in 315 U.S. public and commercial facilities [ATSDR 2001].

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