HHS Public Access

Author manuscript

J Occup Environ Hyg. Author manuscript; available in PMC 2015 December 31.

Published in final edited form as:

J Occup Environ Hyg. 2015 ; 12(5): D47–D53. doi:10.1080/15459624.2014.989362.

Where Occupation and Environment Overlap: US Forest Service Worker Exposure to Libby Amphibole Fibers

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Abstract

The National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of exposures to asbestiform amphibole, known as Libby Amphibole (LA), to personnel from the US Department of Agriculture-Forest Service (USFS) working in the Kootenai National Forest near a former vermiculite mine close to Libby, Montana. LA is associated with vermiculite that was obtained from this mine; mining and processing over many years have resulted in the spread of LA into the surrounding Kootenai Forest where it has been found in tree bark, soil, and forest floor litter. As a result of this and other contamination, Libby and surrounding areas have been designated a “Superfund” site by the US Environmental Protection Agency (EPA). This article describes the application of EPA methods for assessing cancer risks to NIOSH sampling results. Phase-contrast microscopy for airborne asbestos fiber evaluation was found to be less useful than transmission electron microscopy in the presence of interfering organic (plant) fibers. NIOSH Method 7402 was extended by examination of larger areas of the filter, but fiber counts remained low. There are differences between counting rules in NIOSH 7402 and the ISO method used by EPA but these are minor in the context of the uncertainty in concentration estimates from the low counts. Estimates for cancer risk are generally compatible with those previously estimated by the EPA. However, there are limitations to extrapolating these findings of low risk throughout the entire area and to tasks that were not evaluated.

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uoeh.

AUTHORS’ NOTE

During the publication of this article, the EPA released an update of LA toxicity and risk assessments, with an inhalation unit risk (IUR) specific to LA. The Libby IUR doesn’t account for the age at first exposure or years of exposure as does the IUR for other forms of asbestos, but this would not have a major impact on the conclusions presented here. The update also includes a reference concentration for non-cancer endpoints, which were not evaluated in the present study.[17]

INTRODUCTION

Libby, Montana, is located near a former vermiculite mine. The vermiculite deposit is characterized by the presence of amphibole minerals that have crystallized in a fibrous habit similar to that of regulated amphibole asbestos. The composition of these minerals is quite variable through the deposit, but is considered to be primarily winchite, with lesser amounts of richterite, tremolite, and magnesioriebeckite.[1] The US Environmental Protection Agency (EPA) evaluates all mine-related amphibole asbestos types together as “Libby Amphibole” (LA).[2] Raw vermiculite ore from the Libby mine has been estimated to contain up to 26% LA and was dispersed throughout the site as a consequence of mining and milling operations and the use of vermiculite for insulation and soil amendments. In 2002, an area around the mine, including the town of Libby, was classified as a National Priority List Site under “Superfund” legislation due to the presence of LA in the environment.[3] Studies have demonstrated the presence of amphibole fibers in tree-bark, forest floor litter (“duff”) and soil.[4,5] Thousands of acres of the Kootenai National Forest are included under the Superfund site designation. The US Department of Agriculture-Forest Service (USFS) is responsible for managing federal lands in the Kootenai National Forest and USFS workers are required to enter and work in the area. Federal forest operations and management activities specifically related to wildland fire suppression and management decreased in 2008 when a Public Health Emergency was declared by the EPA and the Department of Health and Human Services as a consequence of increased disease associated with elevated LA exposures in the Libby area and nearby town of Troy.[6] However, since then, some non-fire suppression activities, such as trail maintenance and fuels management, have periodically been conducted with strict supervisor review and approval based on need, duration, and time of year. In 2008, an occupational exposure assessment of selected simulated USFS activities was conducted. All samples were analyzed using Transmission Electron Microscopy (TEM); LA was identified in Personal Breathing Zone (PBZ) samples collected during fireline construction and tree measurement activities.[4]

Approximately 40 full-time, permanent USFS workers are employed at the local USFS Ranger Station. Up to 100 additional seasonal workers may be hired during the summer. The work involves land management activities, including civil engineering, trail and road maintenance, forest biology, fuels and timber management, and hydrology. They may also be engaged in fire suppression activities in the event of a wildland fire outbreak. Daily work shifts for both permanent and seasonal workers are typically 8–10 hours, with the longer shifts usually occurring in the summer months when many of the work tasks are outdoors. However, work activities include planning, preparation, and assembly of equipment, and the portion of the shift actually conducted in the field is normally less than eight hours. Job tasks often vary from day-to-day, depending on the type of work assigned, climatic conditions, and the worker’s level of responsibility. Workers may not be required to work outside every day or even every week. It is estimated that the amount of time spent outdoors conducting field work on all routine tasks averages 30 days per year, while fire suppression may require an additional average of 30 days per year.

Since 2008, natural resource management activities (e.g., road and trail maintenance) have been significantly restricted in certain areas of the Kootenai National Forest. The USFS has

not developed specific written protocols for non-wildland fire activities; however, it is common practice to have a supervisor review and approve all proposed activities in this area based on need, duration, and time of year. If an activity is conducted in a designated section of the Superfund area that surrounds the former vermiculite mine, known as Fire Management Unit 3 (FMU3), the USFS attempts to schedule work based on desirable environmental conditions (e.g., when it is raining or there is at least 6" of snow cover) to minimize potential LA exposures. Supervisors make decisions for each activity conducted in this section of the Superfund site relating to entry, personal protective equipment (PPE), and work practices. The respiratory protection program requires full-face powered air purifying respirators or half- mask air-purifying respirators with P-100 filters to be used. Additionally, procedures have been established requiring all workers conducting natural resource management activities in this area to undergo decontamination upon completion of work. USFS has obtained a three-stage mobile decontamination unit and trained employees to deploy and use this unit. Only USFS vehicles are used for conducting work in the Superfund area. The USFS has developed strict written guidelines for wildland fire suppression and response activities in the Superfund area. These guidelines are designed to limit firefighter's exposure to LA by first relying on aviation resources (e.g., water and retardant dropped from helicopters and air-tankers). If ground based firefighting personnel are required, the agency has approximately 15 trained workers (non-seasonal) who have volunteered to conduct wildfire suppression activities in this area. 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 these workers, which consists of baseline medical examination as described in the OSHA asbestos standard, 29 CFR 1910.1001(l) Medical Surveillance.

The National Institute for Occupational Safety and Health (NIOSH) develops and periodically revises recommended exposure limits (RELs) for hazardous substances or conditions in the workplace. NIOSH typically derives a REL based on a quantitative assessment of risk. The REL is the airborne concentration that NIOSH believes would be protective of worker safety and health for a 40-hour week over a 45-year working lifetime if used in combination with engineering and work practice controls, exposure and medical monitoring, posting and labeling of hazards, worker training, and personal protective equipment. NIOSH does not have a REL for asbestiform LA, but designates asbestos as a "Potential Occupational Carcinogen"[7] and assumes LA to be similarly toxic.[8] The NIOSH REL for asbestos of 0.1 fibers per cubic centimeter of air ($f.cm^{-3}$) is a quantitative value based on what has been considered as the analytical limit of quantitation (LOQ) using NIOSH Method 7400[9] with an optical phase-contrast microscope (PCM), and a sample collected over any 100-min period at a flow-rate of 4 $l.min^{-1}$. This is the same concentration value used by the Occupational Safety and Health Administration (OSHA) as a permissible exposure limit (PEL) for asbestos. Any particle meeting the geometric definition of a fiber (3:1 aspect ratio, > 5 um in length) is counted under NIOSH 7400 rules whether or not it is asbestos and this can lead to overestimation of asbestos exposure where non-asbestos particles of similar dimensions are observed. Nevertheless, risk estimates were based on exposure measurements made using the PCM method, and traceability to these

measurements is the reason the method is still useful for evaluating worker exposure to asbestos. It is recognized that there is some residual risk of cancer at the LOQ of the NIOSH method. OSHA considers the residual risk to be 3.4 cancers per thousand workers for a 40-year working lifetime exposure to 0.1 f.cm^{-3}. NIOSH has determined that a risk-free level of exposure to airborne asbestos has not been established.[7,10]

EPA[2] has assessed inhalation pathways for quantitative evaluation of human health risks in the Libby area for the general population and, in some instances, workers. PBZ samples were collected from contractors performing work tasks similar to those performed by the USFS (activity-based sampling, or ABS), including trail maintenance, tree thinning, and stand evaluation to simulate non-fire-fighting tasks, and cutting of firelines by hand and by heavy equipment to simulate firefighting tasks. Thirty samples were collected for each of these two types of simulated activities. However, there remains uncertainty as to whether these surrogate exposures are representative of USFS workers carrying out their tasks, and if these results can be extrapolated to other areas of the forest. This article presents the PBZ exposure measurements of USFS personnel obtained by NIOSH and a comparison of these results with EPA's ABS measurements. Cancer risk estimates were also determined for USFS workers by NIOSH using the same risk calculation procedure as used by the EPA and these were found to be comparable to those calculated by the EPA from their ABS measurements.

METHODS

Activities Monitored

NIOSH conducted their evaluation in the summer of 2012.[11] Tasks evaluated during the four-day period included administrative work, facilities maintenance, trail maintenance, tree stand evaluation, thinning/sawing and piling, rock raking, work in the hydrology laboratory with stream gravels, and fireline construction. All activities were performed within a 6.5-mile radius of the former vermiculite mine (Figure 1). The meteorological conditions included temperatures from 15.8 to 25.5 C°, 20%– 24% humidity, and wind speeds from 8–18 kilometers per hr. Morning dew condensation on vegetation was observed during early morning trials, but no measured precipitation was reported.

Air Sampling and Analytical Methods

One hundred thirty-six full-shift and activity specific PBZ samples were collected from 23 USFS workers performing 10 different tasks in a variety of locations. Samples did not always include time spent in preparation, assembly, and transportation to the field, so that a full-shift sample in the context of this study could be as little as five hours (or less if the worker was only outdoors for the morning or afternoon period). Sampler cassettes were typically worn on the shirt collar. To prevent overloading, the investigators visually observed the filters for debris and changed the cassettes as necessary. A higher pump sampling rate was used for the activity specific sampling to maximize the volume of air collected and improve analytical sensitivity. The cassettes and pumps were removed during lunch breaks and when workers underwent decontamination. Field (10%) and media blanks were submitted with the samples to the analytical laboratory.

All filters in this study were examined by PCM (NIOSH 7400 Method) at the NIOSH contract laboratory and all samples had detectable fibers, with six exceeding the NIOSH REL/OSHA PEL of 0.1 f.cm^{-3}. These six samples were all collected during fireline construction activities. An additional four samples from fireline construction were between 0.05–0.1 f.cm^{3} by PCM analysis. As noted, fibers that are not asbestos or related minerals may also be counted under PCM measurements. The high values found here by PCM were unexpected and aroused suspicion that materials such as organic (plant) fibers or fiberglass were being included in the count. EPA uses TEM[12] as its standard analytical method for ambient air samples because TEM can identify asbestos fibers unequivocally through the use of selected area electron diffraction to determine crystal structure and energy dispersive spectrometry (EDS) to determine elemental composition. NIOSH also recommends in situations where there are interfering fibers that PCM measurements are recalculated using the proportion of asbestos fibers found under TEM by NIOSH Method 7402.[13] Measurements by both methods exclude fibers thinner than a width limit that has been considered the limit of visibility under PCM and this is referred to as a PCM-equivalent (PCMe) count. All of the PBZ samples that exceeded the NIOSH REL under PCM and representative PBZ samples from the other activities monitored (a total of 33 samples) were further analyzed by TEM to determine whether the fibers detected by the PCM analysis were LA. To balance sensitivity and cost, the following approach was taken, which is based on NIOSH Method 7402, but generally compatible with International Organization for Standardization (ISO) Method 10312.[12] NIOSH fiber-counting rules are similar, though not completely identical to those of ISO 10312, but, in practice, all fibers identified in this study under TEM as meeting the NIOSH 7402 definition of a fiber would also meet the definition of a PCMe fiber under ISO 10312. A major difference between the procedures is that NIOSH 7402 counts a fiber crossing a grid-opening as a half-fiber, while ISO 10312 would count it as a single fiber.

Most of the samples analyzed by TEM were collected at a flow-rate of 2 L/min per min over a 3-hr, or longer, period. The smallest unit detectable under TEM by NIOSH 7402 is one-half fiber (a fiber crossing the boundary of a TEM grid field). One-half fiber found in 80 TEM grid fields for a sample as described above gives a concentration of 0.0006 f.cm^{-3}, subject to the uncertainty inherent in counting. Using the same calculation EPA used in their assessment of USFS activities, this would equal a cancer risk of approximately 1 in one million (1 E-06). Thus, only 80 fields were evaluated if no fibers were detected. If even 0.5 fiber was detected, the number of evaluated fields was expanded to 200 in an attempt to assure reasonable confidence in the numbers. As an example, based on a Poisson distribution, finding 3 fibers gives an assurance that the actual number is between 0 and 8 (hence 2.99 fibers is considered the limit of detection, or LOD, for ISO 10312). This necessitated the preparation of additional TEM grids. Grids were examined under low-power (5600 × magnification) and any mineral fibers observed were subsequently examined under higher power (15,000 ×) for identification. Results from multiple samples taken on a single individual during the course of a day (e.g., morning and afternoon) were entered into the standard formula for determining time-weighted average (TWA) concentrations. Samples with no fibers detected were given values of one-half fiber detected as the most conservative assumption for these calculations. Unsampled portions of an 8-hour day were

assigned a concentration of zero, since it can be assumed that the workers were engaged in tasks which carried minimal risk of exposure to LA, such as driving to and from the field sites, donning equipment, changing clothes, or discussing work assignments.

The particles identified as LA fibers by the NIOSH contract laboratory under TEM had some unusual attributes. The contract laboratory had not detected potassium and the fibers also appeared to contain considerable amounts of iron and were generally thicker than previously published median widths of airborne LA fibers. Therefore, some of the TEM grids prepared by the NIOSH contract laboratory were submitted to the EPA Region 8 contract laboratory for confirmatory TEM analysis. This laboratory performed elemental analysis on 11 amphibole asbestos structures using EDS. The sodium and potassium data had a distribution comparable to that of asbestiform amphibole from the Libby mine as plotted by Meeker et al. (2003). The EDS data were used to calculate cation ratios normalized to 23 oxygens and a formula calculated according to the approach of Leake et al.[14] The mineral species were considered to be actinolite (1structure), winchite (6 structures), and richterite (4 structures). The average ratio of Fe to (Fe+Mg) was 14% (range 8.5 to 26%) and the average ratio of Fe to (Fe+Mg) for the laboratory analyses of the Libby Starting Material (a blended reference from the mine) is 12.6% (range 6.7 to 36%), assuming all Fe is Fe^{2+}. In addition, the same type of morphology (fiber bundling, terminated ends of individual fibrils, wide range of fiber aspect ratios including very long narrow fibers) found in the Libby Starting Material was observed in the NIOSH samples. Although the asbestos structures observed were considered by the EPA contract laboratory to be generally wider than those they had typically observed in prior air samples from the environment around Libby, it was concluded by them that the most likely origin of the amphibole fibers is the former vermiculite mine at Libby.

RESULTS

The results of fiber concentrations from the TEM analyses are given in Table I. Where single samples had been taken for at least 300 min or where samples on the same person on the same day could be combined to give more than 300 min of coverage, an 8-hrTWAconcentrationwas calculated assuming zero exposure during the unsampled periods (Table II). Twelve TWA samples could be calculated, six for sawyers (i.e., workers who operate chainsaws and cut brush and trees) involved in fireline construction, three for swampers (i.e., workers who assist sawyers by clearing away brush, limbs, and small trees), two for workers measuring tree stands, and one for a worker involved in clean-up at the fire cache. Any sample where no fibers were found was given 0.5 fibers and the TWA concentration calculated with this value but given as “less than”. Therefore, all concentration results preceded by a “less-than” sign are likely to be conservative overestimates. Only two results, one for a sawyer and one for a swamper, had LA fibers detected on both morning and afternoon samples and thus could be considered full-shift samples with quantitative data. In addition, only two samples included three or more fibers and thus could be considered above the LOD of the ISO method. Any evaluation of the results should keep in mind the large uncertainty associated with results based on fewer than three fibers. Any impact from the difference in count rules between NIOSH 7402 and ISO

13012 procedures would contribute less to the expanded uncertainty than was contributed by the low counts.

DISCUSSION

Risk calculations

Cancer risk estimates from these work activities were calculated from equations used by the EPA[15] in their assessment of asbestos exposures at Superfund sites. An inhalation unit risk (IUR) value of 0.0902 was used to calculate the upper-bound excess lifetime cancer risk estimated to result from exposure that begins at age 18 years and continues for 40 years. This value was obtained from Table E-4 of the EPA's Framework.[15] The assumptions of work duration previously made by the EPA[2] for the USFS workers in this geographical area of the Kootenai National Forest were an 8-hr daily exposure for 30 days in a year. The fraction of a 24-hr day is then multiplied by the fraction of a 365-day year to calculate a time-weighting factor (TWF) of 0.0274. The same values were used to derive the risk estimates in Table II. In discussion with the USFS, it was confirmed that 30 days per year is the likely maximum time a worker spends in all tasks related to trail maintenance, tree thinning, and stand examination activities (together making up one category of activities considered by the EPA,[2]) but it was also confirmed that fireline construction should be retained as a separate category since it is possible that local USFS workers may spend up to 30 additional days per year in fireline construction, and because firefighters who do not normally work in the district may on occasion be involved in fireline construction. Six TWA data points are included in each category, but the results are essentially the same across the categories, with a highest single excess lifetime cancer risk estimate in each category being < 1 E-06. These estimates do not include additional exposure from any work in the other category or from non-work activities. Since the local workers may reside or may undertake recreational activities in areas of concern, potential exposures other than those investigated here should be assessed through a comprehensive exposure matrix evaluation. It is difficult to extrapolate long-term mean exposure concentrations from a relatively few samples where the majority are below the LOD and because results are subject to uncertainty arising from random variation between samples collected on multiple individuals carrying out the same task (inter-worker variability) and between samples collected on the same individual performing the same task on different days in different areas (intra-worker variability). If the values in Table II for results with no fibers detected (all but two) are assumed to have one-half fiber and all are combined, then a conservatively high estimate of the mean is 7 E-7 with a 95% upper confidence limit of 8 E-7 and with a 95% upper tolerance limit on the 95th percentile of the distribution of 2 E-6.

Comparison to prior EPA studies

EPA risk assessments are derived for the purpose of informing site clean-up decisions and not for making decisions with regard to worker health and safety. In the EPA study of USFS activities,[2] PBZ samples were collected from two individuals engaged in several activities that simulated actions performed by USFS workers, including forest management activities and firefighting activities (cutting firelines). Cancer risk estimates were calculated using the exposure assumptions described above and using the best estimate exposure concentration

values. Based on an average concentration of 0.0006 s/cc (LA structures per cubic centimeter), ranging from zero to 0.0016 s/cc, risk estimates for forest management activities were at or below 4 E-06, with an average across all stations and activities of 2 E-06. Based on an average concentration of 0.0089 s/cc, ranging from zero to 0.0267 s/cc, risk estimates for firefighting activities were at or below 7 E-05, with an average across all stations and activities of 2 E-05. These EPA estimates are somewhat higher than the values found in this study, but given differences in analytical methodology and, more importantly, the measurement uncertainty inherent in low fiber counts, both studies can be considered to support the conclusion that cancer risks to USFS workers from LA exposures conducting individual activities at these sampling locations are likely to be low. However, if the inhalation unit risk value changes, recalculation may change this conclusion.

Limitations

This study did not find evidence that USFS worker exposure to LA presents a high risk for cancer while performing activities in the areas evaluated, based on current estimates of inhalation unit risk. However, these findings may not be representative of potential exposures in other areas. Additionally, no sampling was conducted to evaluate exposure during a wildland fire or prescribed burn and the results presented here cannot be extrapolated to firefighting activities. Lastly, the USFS personnel are generally local residents who may have exposures to LA from other sources, depending on their lifestyle and indoor and outdoor activities.[16]

CONCLUSION

EM analysis of samples collected in a heavily forested area allowed NIOSH to more precisely characterize exposures of USFS workers to LA in the Kootenai National Forest. However, the numbers of LA fibers detected under TEM analysis were small, even with additional observations from the samples, and this leads to some uncertainties in the results. LA exposure concentrations determined by NIOSH are generally similar to surrogate ABS measurements previously made by the EPA and lead to similar conclusions with respect to cancer risk using EPA's previously published criteria for risk assessment. While cancer risks from this specific evaluation are low, there are limitations to extrapolating this conclusion to all work in the Kootenai National Forest since exposures may vary across the area by task and according to the spatial distribution of contamination, soil and vegetation type, and environmental conditions.

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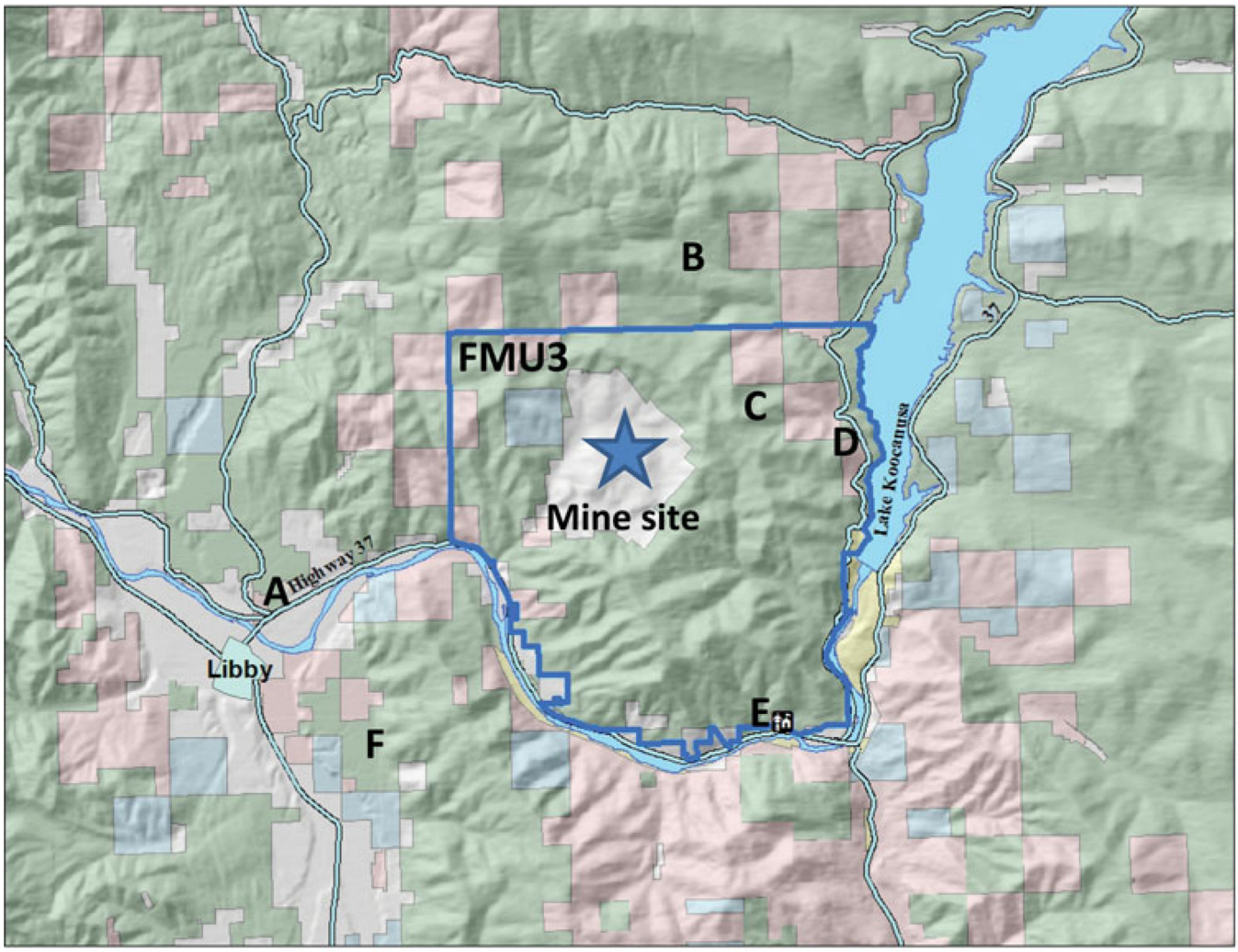

FIGURE 1.

Sampling locations. Key: A: Fire cache fuel reduction and cleanup and other administrative and tool maintenance activities and hydrology lab: 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 activities: 3.9 miles from mine site; E: Ranger station-lawn care and maintenance; office activities; F: Fireline construction: 6.3 miles from mine site.

TABLE I

Air Sampling Data from TEM [A]

DATE	Location (see Figure 1)	Job	Sample #	Total Time (min)	No of fibers	Fibers. cm^{-3}	LOD when fibers found
8/13	D	Thinning	134	238	0	< 0.0002	
8/13	D	Thinning	145	228	0	< 0.00024	
8/13	D	Thinning	127	188	0	< 0.00038	
8/13	A Hydrology Lab	Sieving	126	270	0	< 0.00040	
8/14	F	Fireline construction	61	237	3	0.00110	< 0.00018
8/14	F	Fireline construction	125	169	0	< 0.00028	
8/14	F	Fireline construction	45	235	2	0.00074	< 0.00018
8/14	F	Fireline construction	105	238	0.5	0.00030	< 0.00030
8/14	F	Fireline construction	68	218	0	< 0.00042	
8/14	F	Fireline construction	51	156	1	0.00036	< 0.00018
8/14	F	Fireline construction	89	223	0	< 0.00033	
8/14	F	Fireline construction	74	159	0	< 0.00030	
8/14	F	Fireline construction	24	217	1	0.00042	< 0.00021
8/14	F	Fireline construction	116	235	0	< 0.00030	
8/14	F	Fireline construction	39	206	0	< 0.00036	
8/14	F	Fireline construction	78	155	0	< 0.00031	
8/14	C	Swamper	148	186	4	0.00120	< 0.00015
8/14	C	Swamper	16	159	0	< 0.00045	
8/14	C	Swamper	128	183	0	< 0.00039	
8/14	C	Swamper	49	162	1.5	0.00053	< 0.00017
8/14	C	Swamper (sawing)	34	201	3	0.00085	< 0.00014
8/14	C	Swamper	31	160	1	0.00036	< 0.00018
8/15	B	Tree stand measurement	70	456	0	< 0.00016	
8/15	B	Tree stand measurement	38	154	0	< 0.0003	
8/15	B	Tree stand measurement	62	303	0	< 0.00025	
8/15	B	Tree stand measurement	95	205	0	< 0.00036	
8/15	B	Tree stand measurement	84	152	0	< 0.00031	
8/15	B	Tree stand measurement	106	244	0	< 0.00019	

DATE	Location (see Figure 1)	Job	Sample #	Total Time (min)	No of fibers	Fibers. cm^{-3}	LOD when fibers found
8/16	D	Road Raking	48	293	0	< 0.00016	
8/16	A Hydrology Lab	Sieving	50	114	0	< 0.00041	
8/16	A Fire Cache	Thinning, sawing, piling	103	196	0	< 0.00024	
8/16	A Fire Cache	Thinning, sawing, piling	17	191	2	0.00061	< 0.00015
8/16	A Fire Cache	Thinning, sawing, piling	142	137	0	< 0.00053	

[A] All fibers are LA and meet PCMe geometric criteria.

TABLE II

Eight-Hour TWA Calculations with Cancer Risk Calculations Following EPA Procedure, 2011

DATE	Location (see Figure 1)	Job	Total Time (mins)	8-Hr TWA (fibers.cm^{-3})	Cancer risk (30 8-hr days/year)
		Non-fireline construction activities			
8/14	C	Swamper	345	< 0.00047	<1 E-06
8/14	C	Swamper	345	< 0.00017	<5 E-07
8/14	C	Swamper	361	0.00036	9 E-07
8/15	B	Tree stand measurement	456	< 0.00015	<4 E-07
8/15	B	Tree stand measurement	508#	< 0.00025	<7 E-07
8/16	A Fire Cache	Thinning, sawing, piling	328	< 0.00024	<6 E-07
		Fireline construction			
8/14	F	Fireline construction	406	< 0.00054	<1 E-06
8/14	F	Fireline construction	473	0.00036	9 E-07
8/14	F	Fireline construction	374	< 0.00019	<5 E-07
8/14	F	Fireline construction	382	< 0.00016	<4 E-07
8/14	F	Fireline construction	452	< 0.00019	<5 E-07
8/14	F	Fireline construction	361	< 0.00016	<4 E-07

Note:

#508 min used as denominator.