Health Consultation

Evaluation of Asbestos Exposures at

ILLINOIS BEACH STATE PARK

ZION, LAKE COUNTY, ILLINOIS

EPA FACILITY ID: ILD984840140

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

PUBLIC COMMENT RELEASE

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Prepared By:

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

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EXECUTIVE SUMMARY

Concerns about asbestos contamination at Illinois Beach State Park (IBSP) were initiated when pieces of transite pipe, siding, and roofing materials suspected of containing pieces of asbestos containing material (ACM) were found washed up on shore in the late 1990s. There are several potential sources of the ACM including building and infrastructure materials from former beachfront homes that were located on what is now IBSP property, materials from the former Johns-Manville site immediately south of IBSP, nourishment sands applied to the feeder beach at the north end of IBSP, and a former rifle range in the Camp Logan area of the North Unit that was comprised of waste material from Johns Manville.

Since that time, several investigations have been conducted to characterize this contamination and to evaluate levels of human exposure. In 2000, the Illinois Department of Public Health (IDPH) and ATSDR published a Public Health Assessment that concluded that there was no apparent public health hazard at IBSP. However, it was recommended that warning signs and flyers be posted to alert the public about the possible presence of ACM on the beach, and continuation of periodic beach inspection and ACM removal. In 2006, the Center for Excellence in Environmental Health at the University of Illinois at Chicago (UIC) School of Public Health published an evaluation of IBSP. The UIC study evaluated the levels of asbestos in various beach areas at IBSP, comparing the results to other beaches on the southwestern shoreline of Lake Michigan. Results of this study found statistically elevated levels of potentially releasable asbestos structures in sands from IBSP North Unit relative to other beaches. However, the estimated levels of asbestos exposure were below the risk levels used by the U.S. Environmental Protection Agency (USEPA) as a threshold for taking action. In 2006, ATSDR worked with the Illinois Department of Natural Resources (IDNR) to conduct an activity-based sampling to more directly measure levels of exposure to asbestos at IBSP.

Most recently, USEPA conducted an intensive activity-based sampling study in September 2007. This sampling represents a very extensive and detailed effort to characterize potential exposures to individuals using the beaches at IBSP. The sampling simulated a variety of activities that would be typical for recreational users of the beach, including sand playing, volleyball, jogging, sun bathing, and sand raking. The results showed that only 3 of the 154 activity-based samples detected any asbestos fibers of the size that contributes to cancer risk in current assessment methods. This ATSDR Health Consultation reviews the 2007 EPA sampling data to determine potential asbestos exposures to recreational users of IBSP and estimated the potential risk of exposures to users of the beach. The conclusion of this assessment of potential asbestos exposure at IBSP is that *recreational use of the beach is not expected to harm people's health*. This conclusion is based on the fact that very low levels of asbestos fibers were detected with extensive sampling that directly evaluated how people could be exposed. This conclusion is also consistent with those of previous investigations.

It is acknowledged that ACM does periodically wash up on IBSP shoreline. Although recreational activities on the beach do not pose a public health hazard, the public should be made aware that ACM may be present and direct contact should be avoided. ATSDR recommends that the Illinois Department of Natural Resources (IDNR) continue with regular beach sweeps to collect ACM and to continue efforts to educate IBSP users about the potential hazards of ACM.

BACKGROUND

STATEMENT OF ISSUES

Several investigations of asbestos contamination at IBSP have been conducted over the past few years, the most recent being an Exposure Investigation (EI) conducted by ATSDR and published in October 2007 (1). A peer review of the ATSDR EI by the U.S. Environmental Protection Agency (USEPA) Technical Review Workgroup on Asbestos (TRW-Asbestos) recommended that additional activity-based sampling be performed to more completely characterize potential exposure to recreational users of the beach areas at IBSP. In September 2007, USEPA conducted a large-scale activity-based sampling study (2). ATSDR has prepared this Health Consultation to evaluate the results of the USEPA activity based sampling to determine the public health implications.

SITE DESCRIPTION AND HISTORY

IBSP (known as Adeline Jay Geo-Karis Illinois Beach State Park) consists of 6.5 miles of Lake Michigan shoreline in the city of Zion, Lake County, Illinois. It is bordered by the North Point Marina to the north, the town of Zion to the west, and the Johns-Manville National Priorities List (NPL) hazardous waste site to the south. IBSP encompasses 4,160 acres and receives an average of approximately 1.7 million visits a year (3). Recreational activities available include camping, swimming, fishing, hiking, bicycling, and picnicking. Facilities within and near IBSP boundaries include a 244-unit campground, two major public swimming areas, several inland fishing ponds, a visitor center, the Commonwealth Edison Power Plant, and the Illinois Beach Resort and Conference Center. Besides seasonal tourism, IBSP holds special events that draw visitors, including the In-Campground Camper Show in May and the National Jet Ski Championships in July. IBSP is a unique natural resource with the only remaining Lake Michigan beach ridge shoreline left in the state. Glacial advance and retreat created the area that left dunes, swales, marshes, and a variety of wildlife and vegetation in the area. Before becoming a state park, the area was used for military training. In 1948, the State of Illinois acquired the first parcels of what is now IBSP.

In late 1997, pieces of transite pipe, siding, and roofing materials suspected of containing asbestos were found scattered along the beach. In February 1998, Illinois Department of Natural Resources (IDNR) collected two bulk samples of the material and found they contained asbestos fibers. Following this discovery, IDNR began an investigation to determine the extent and possible source of asbestos contamination.

Potential sources of asbestos material at IBSP

> **Former housing area**: former beachfront homes that have since washed into Lake Michigan. Much of the ACM found at IBSP is common construction material used in the past. According to historical maps, the present lakeshore contained about 129 homes that wave action destroyed and washed into the lake. This information has been presented in previous documents (1,3,5).

Johns-Manville Superfund Site: site immediately south of IBSP. This plant manufactured a variety of roofing, flooring, wall covering, and insulating materials from 1922 - 1988. The raw materials used at Johns-Manville include Portland cement, asphalt, paper, and asbestos. A 150-acre parcel of the property was used for disposal of asbestos containing material (ACM) and was placed on the NPL in 1983[a].

Application of nourishment sands to IBSP: Currently, IBSP requires 80,000 – 100,000 cubic yards (yds^3) of sand per year to prevent erosion, particularly to the North Unit beaches (4). Several sources of nourishment sand have been used at the beach. The tests for asbestos in the wide variety of past and potential sources of nourishment sand for IBSP has previously been reviewed (5). Between 1987 and 1989, the excavation and dredging of the 72-acre basin for North Point Marina involved removal of an estimated 1.5 million yds^3 of sand and gravelly sand by slurry-pipe discharge, and application to the feeder beach on the North Unit of IBSP. Other sources of feeder sands at the North Unit are summarized in a report by the University of Illinois School of Public Health (5), including sand dredged from the cooling water channel at the Midwest Generation coal-fired power plant. The cooling water channel, which is located just south of the Johns-Manville property, may have contained ACM. This sand was used for beach nourishment sand when it was deposited on IBSP North Unit feeder beach in 1995. In 1999, 2002, 2004, 2007 and 2008 the IDNR placed quarried sand on the North Unit feeder beach. In 2008 the U.S. Army Corps of Engineers placed sand dredged from Waukegan Harbor-Outer Harbor near-shore in the area of the North Unit feeder beach. In 2005, 2006 and 2007 the IDNR placed sand dredged from the Prairie Harbor Marina on the North Unit feeder beach. In 1995, 1999, 2001, 2002, 2003, 2004, 2005, 2007 and 2008 the IDNR place sand dredged from North Point Marina near-shore in the area of the North Unit feeder beach (4).

Some of these sand sources have been visually inspected for ACM or tested for asbestos using either polarized light microscopy (PLM) or transmission electron microscopy (TEM) (6) Asbestos has been detected in some of these samples at low levels.

Former rifle range in the Camp Logan area. A rifle range was built for the 1959 Pan American games, which contained a large berm built with factory waste material donated by Johns-Manville. Wave action may have destroyed this berm that also potentially contained ACM.

Previous Asbestos Sampling and Public Health Evaluations at IBSP

Since the discovery of ACM on IBSP, several public health and environmental agencies have been involved in either sampling or public health analysis of asbestos at IBSP. These agencies have broadly concluded that the potential for human exposure to asbestos is low and the resulting threat to public health is minimal.

[a] http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=0500197

Illinois Department of Natural Resources- 1998

In 1998, the IDNR contracted Hanson Engineers to sample and report on the extent of ACM contamination at IBSP (3). This undertaking was part of an emergency declaration from IDNR, and the sampling plan was reviewed and approved by the Illinois Environmental Protection Agency (IEPA), Illinois Department of Public Health (IDPH) and the Illinois Office of the Attorney General (IOAG). This investigation included bulk analysis of debris, air sampling of debris pick up activities, general air sampling to assess public exposure, bulk sand sampling, and water sampling. The results of the investigation, conducted in March 1998, confirmed the presence of asbestos in bulk ACM samples (chrysotile at 5-30%; crocidolite at 5-20%) collected along the beach. Of the 181 sand samples analyzed by PLM, no samples exceeded the detection limit for the method (1%). However, 10 samples had detectable asbestos below 1%, but could not be quantified and were labeled as trace detections. The results for aggressive air sampling (agitation of surfaces with a leaf blower) at various locations at IBSP were non-detect for asbestos using TEM analysis (detection limit: 0.005 f/cc). The public health implications of these data was reviewed in the 2000 Public Health Assessment described below.

ATSDR/Illinois Department of Public Health- 2000

In 2000, ATSDR released a Public Health Assessment, prepared by IDPH under a cooperative agreement program, based on data collected by Hanson Engineers for IDNR in 1998, described above (3). The Public Health Assessment was conducted at the request of IDNR. Because of the low asbestos levels found, the fact that most of the ACM is non-friable, and the consideration of current toxicological information reviews, exposures would not be expected to cause adverse health effects in IBSP workers or visitors. IDPH concluded that information available indicated that there was *no apparent public health hazard*[b] for exposure to asbestos at IBSP.

University of Illinois-Chicago School of Public Health- 2006

In 2006, the University of Illinois-Chicago School of Public Health released their report entitled, "Illinois Beach State Park: Determination of Asbestos Contamination in Beach Nourishment Sand, Final Report of Findings" (5). This project was undertaken to address several questions raised by the Illinois Attorney General's Asbestos Task Force. The UIC study evaluated the levels of asbestos in various beach areas at IBSP, comparing the results to other beaches on the southwestern shoreline of Lake Michigan. Sample preparation and analysis was performed using the Superfund Method for the Determination of Releasable Asbestos in Soils and Bulk Materials (6) as modified by the Draft Elutriator Method for the Determination of Asbestos in Soils and Bulk Material. This method analyzes the abundance of asbestos structures per gram of airborne particulate matter up to 10 micrometers in size (PM10) in the sample material. Results of this study found statistically elevated levels of asbestos structures could be released from sand samples taken in the IBSP North Unit sand, relative to other beaches on the southwestern shoreline. However, the results of this analysis do not reflect actual levels of human exposure, only the potential for becoming airborne under laboratory conditions. Using this information in

[b] Defined as conditions where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

combination with modeled estimates of PM10 concentrations in the air, the estimated air concentrations of asbestos fibers for IBSP samples were calculated. These estimated air concentrations of asbestos fibers (5) were well below the acceptable target cancer risk range (10^{-6}, or one-in-a-million, to 10^{-4}, or one-in-ten thousand, excess cancer risk) used by USEPA for making risk management decisions.

The study also evaluated two potential lake-bottom sources of beach replenishment sand. The potential air emissions of asbestos fibers were modeled and used to estimate air concentrations. The results concluded that the use of these sources for beach nourishment would represent a minimal risk to beach users.

Agency for Toxic Substances and Disease Registry- 2007

In 2007, ATSDR released an Exposure Investigation report for IBSP (1). The investigation was conducted as a collaborative effort between ATSDR and IDNR, and included activity-based air sampling and bulk sand sampling to estimate asbestos exposure to typical beach users. The simulated activities were sand castle construction and beach maintenance activities. Personal monitor air samples during the sand castle construction showed only 1 sample with any asbestos fibers being detected. That detection was at a level (less than 0.0027 fibers/cubic centimeter) similar to that also found at the reference locations. The reference stations were located in areas of IBSP that would not be impacted by potential ACM on the beach. Simulated beach maintenance activities on the north beach (a tractor was used to drag a grating across the beach) resulted in slight elevations in asbestos levels compared to the reference locations. The conclusions of this assessment were that the activities ATSDR simulated for children playing in the sand posed no apparent public health hazard for IBSP beach users. Although simulation of beach grading activity did result in measurable dispersion of asbestos fibers into the air, this activity is no longer conducted at IBSP and does not represent a realistic exposure for recreational users of IBSP.

A peer review of the ATSDR EI by the USEPA Technical Review Workgroup for Asbestos (TRW-Asbestos) recommended that additional activity-based sampling be performed to more completely characterize potential exposure over a wider range of recreational activities on the beach areas at IBSP. In response to that recommendation, USEPA planned a more extensive activity-based sampling effort. A review of the methodology, the results, and an evaluation of health risks is presented in this document.

2007 USEPA ACTIVITY-BASED SAMPLING DATA

SAMPLING AND ANALYSIS PLAN

The Sampling and Analysis Plan for the 2007 USEPA Exposure Assessment is in Appendix E of the Quality Assurance/Quality Control Plan (QAPP) for the project (7). This document describes the specific procedures for collecting, processing, and analyzing the samples. The primary goal of this study was to further characterize potential human exposures to asbestos fibers at IBSP. To meet this goal, specific data quality objectives were established to determine 1) the concentration of asbestos fibers in air in the study area during typical activities and conditions, 2)

the levels of asbestos exposures for individuals involved in typical uses of these areas, 3) the background concentrations of asbestos fibers from off-site sources, and 4) the concentration of asbestos in study area soils that may be a source for airborne fibers.

Sampling Conditions: The USEPA-Environmental Response Team (ERT) and their contractor (REAC) conducted sampling at IBSP site from Monday September 4 through Wednesday September 12, 2007 (8). Weather conditions varied during the 9 days of sampling. During the first 3 days of sampling, the air temperatures varied from low 70s to low 90s, with light winds (<5 up to 15 mph) predominantly from the south and southwest. The sands were extremely dry during this time. Outdoor sampling was cancelled due to rain on days 4 and 7. Days 5-9 were cooler, with daytime highs in the mid-70s, and with light winds (<5 up to 8 mph). The daily soil moisture level averaged ranged from 0.3 to 1.6%.

Sampling Activities and Locations: Activity-based sampling was conducted at locations along the entire 5 mile length of IBSP shoreline, and included 26 different events and the following specific activities. Detailed procedures for conducting these simulated activities are described in the references cited in the footnote.

- Raking[c]
- ATV riding[c]
- Jogging[c]
- Child playing[c]
- Indoor sweeping[d]
- Volleyball[d]
- Soccer[e]
- Sunbathing[e]

Air Sampling Methods: The target duration for all activity-based sampling was two hours and all participants donned personal protective equipment (PPE) and were fitted with personal high and low volume sampling pumps within backpacks with the filter cassette secured to the shoulder straps near the participant's lapels in the breathing zone. For all air sampling locations, an asbestos sampling train consisting of a 0.8-micron (μm), 25-millimeter (mm) mixed cellulose ester (MCE) filter connected to a sampling pump was used. The top cover from the cowl extension on the sampling cassette was removed ("open-face") and the cassette oriented face down at an angle of at least 45 degrees.

The perimeter and reference air samples were collected using AirCon II samplers, calibrated to 10 liters (L)/minute (min). For activity-based sampling activities, QuickTake 30 sampling

[c] United States Environmental Protection Agency (USEPA) Environmental Response Team (ERT) Standard Operating Procedure (SOP) 2084, *Activity-Based Air Sampling for Asbestos.*

[d] Response, Engineering and Analytical Contract (REAC) document 0279-DQAPP-090407, Quality Assurance Project Plan for Illinois Beach State Park Asbestos Exposure Assessment.

[e] REAC document 0279-DWPA1-032108, Work Plan for Work Assignment No. 0-279, Amendment 1, Illinois Beach State Park Exposure Asbestos Exposure Assessment.

pumps calibrated to 10 L/min and SKC personal sampling pumps calibrated to a flow rate of 3.5 L/min were used to collect high and low volume personal air samples over a two-hour period.

Filter pore size- The pore size of the filters used in the sampling was 0.8 micron, which is within the range of pore sizes recommended by NIOSH methods 7400 (9) and 7402 (10). The pore size recommended in the ISO 10312 method is a 0.45 micron pore size. However, there has been significant difficulty in using the 0.45 micron for activity-based sampling events that have been conducted by USEPA. The elevated backpressure that occurs with the 0.45 micron filter cassette results in a significant reduction in airflow and frequent failure of the battery-powered personal monitoring pumps. The decreased flow rate significantly reduces the volume of air that can be sampled and results in an inability to meet the analytical sensitivity requirements for comparison to health-based criteria. A USEPA study comparing the chrysotile asbestos fiber counts for collection of samples onto either 0.45 micron or 0.8 micron filters showed no difference in the counting efficiency between these filters for fibers greater than 5 microns in length (11,12). There was a slight difference in the detection of fibers between 0.5-5.0 microns in length. Chrysotile asbestos was selected for this study since it tends to occur as thinner fibers that can be more difficult to detect, and serve as a more sensitive test material for comparing counting efficiencies between the different filters. Although amphibole fibers were not used in this study, it would be expected that amphibole asbestos fibers would have a higher counting efficiency than chrysotile fibers since amphibole fibers are wider. The current quantitative assessment of cancer risk for asbestos exposure focuses specifically on fibers with lengths greater than 5.0 microns. Therefore, the 0.8 micron filters have been viewed as the preferred filter size for activity-based asbestos sampling.

Filter over-loading- An objective of the activity-based sampling methods is to collect sufficient air volumes to reach the analytical sensitivity levels needed to assess levels of potential exposure. A challenge of using high volume pumps, in situations where the specific activities may generate significant amounts of non-fibrous particulate material, is the potential for overloading the surface of the sampling filters. Filters that become overloaded are unable to be analyzed by the direct method. To compensate for this potential problem, co-located samples were collected at different flow rates to allow for the analysis of at least one filter that can be used to represent that sampling event. Filters collecting air of a lower air flow rate are less likely to become overloaded than at high flow rates.

Asbestos Analytical Methods: Laboratory analysis of samples for asbestos content was performed at Material Analytical Services (MAS) in Atlanta, GA. The air samples were analyzed by Transmission Electron Microscopy (TEM) based on the International Organization for Standardization (ISO), Method 10312 (13), with some modifications recommended by the TRW-Asbestos (14). These modifications include counting fibers greater than 0.5 microns in length (USEPA Superfund method- EPASM) and a fiber counting criteria referred to as PCME (phase contrast microscopy equivalent), which are defined as fibers greater than 5.0 microns in length, width between 0.25 and 3.0 microns, and aspect ratio (length/width) greater than 3:1 (14). The analytical sensitivity objective was set at 0.000167 structures per cubic centimeter (s/cc), with a calculated detection limit of 0.0005 s/cc. The analytical sensitivity of specific samples may have varied based on the volume of air collected with the sampling. For each structure, the dimensions (length and width) was measured and mineralogy was determined.

Sand Sampling Methods: A total of 61 bulk sand samples were collected from each of the activity-based sampling locations. Each sample represented a five-point composite sample of sand material with the activity area. The samples were homogenized on the site, shipped to the laboratory and analyzed for asbestos content using the California Air Resources Board method 435 (15). The CARB method is a polarized light microscopic method that has received regulatory acceptance for detecting asbestos fibers in bulk material, with an analytical sensitivity of 0.25%.

Dust Sampling Method: Another potential exposure pathway could be tracking of asbestos fibers from the beach areas into indoor spaces, as well as onto clothing and other articles. Microvacuum samples were collected within the interior of several buildings (IBSP office and women's bathroom on North Unit). Microvacuum samples were also taken on the ATVs, beach towels, shorts and sandals used in the activity-based sampling events. To ensure full contact with the sand, sampling participants were instructed to aggressively dirty the beach articles by grinding them into the sand and tossing sand onto the articles. Samples were taken at 23 different locations. The microvacuum samples were analyzed using ASTM D5755-03 (16).

RESULTS

The air sampling results are reported using the fiber counting criteria that is based on the ISO Method 10312, as modified by ISO 10312 Appendix E and the TRW-Asbestos (14). The fiber counts were recorded using both the USEPA Superfund Method (EPASM) and the Phase Contrast Microscopy Equivalent method (PCME). The EPASM method counts all asbestos structures with a length greater than 0.5 microns and an aspect ratio (length:width) greater than 3:1. The PCME method counts asbestos structures of dimensions that would be counted with the PCM method- having a length greater than 5 microns, an aspect ratio greater than 3:1, and a width between 0.25 and 3 microns. The epidemiological studies of cancer effects resulting from asbestos exposure in workers used the PCM method (optical microscopy), which counts fibers of similar dimensions to the PCME method (electron microscopy). Therefore, the PCME fiber counts were used as the basis for the health hazard assessment in this document. Both the EPASM and PCME fiber counts are presented in data tables in this report to provide a more complete characterization of all the fibers that were detected.

Ambient Reference Samples: Ambient reference samples were taken at locations along the shoreline (either before sampling began or at times when activity-based sampling events were not occurring at that location) and at locations away from the beach (North Unit- remote location near Camp Logan about 1 kilometer (km) inland from shoreline; South Unit- at the Nature Center building about 0.5 km inland from shoreline).

Of the 20 ambient reference samples analyzed, 2 had detections of asbestos fibers. Both of these detections (out of 12 analyzed samples from that location) were at the Nature Center in the South Unit, with concentrations at the lower limit of analytical sensitivity (0.000167 f/cc). Both of these detections were amphibole asbestos fibers (actinolite and asbestos fibers similar to Libby amphibole [17]). All of the 8 ambient reference samples analyzed from the North Unit location were non-detect for asbestos fibers.

Libby amphiboles: The term "Libby amphiboles" refers to a variety of asbestos fibers that have been detected in vermiculite ore material from the mine in Libby, Montana (17). It includes tremolite and actinolite asbestos, but also several other varieties such as winchite and richterite asbestos. Asbestiform fibers, acicular (needlelike) particles, particles showing curvature, and cleavage fragments are also found in the Libby amphibole. Although this classification term has derived from a characterization of amphiboles from the Libby mine, the identification of a Libby amphibole fiber in IBSP sample does not necessarily mean that the source of this asbestos was from Libby, Montana. It reflects a determination that the fiber has geochemical similarity to the amphiboles from the Libby mine.

Activity-based Air Samples: The activity-based sampling included 26 different sampling events at locations spanning along the entire 5 miles of beachfront at IBSP. Specific areas where these sampling activities were conducted are shown as overlays of aerial photographs (Figures 1 and 2, Appendix B). As shown in Table 4 (Appendix B), asbestos fibers of any length greater than 0.5 microns were detected in 13 of the 201 air samples that were collected and analyzed. The samples with detections included: reference samples, perimeter locations from ATV riding, children playing, jogging, soccer, and sweeping inside buildings. However, most of these detections were at concentrations at the lower limit of sensitivity for the analysis (Table 3- Appendix B). In addition, only 3 samples had fibers with dimensions that are relevant for a risk-based evaluation, referred to as PCME fibers (greater than 5.0 microns in length, width between 0.25 and 3.0 microns, and aspect ratio greater than 3:1). Table 4 and Figure 3 (Appendix C) shows the dimensions and mineralogical identity of each fiber that was detected in the analysis of IBSP samples. The detected fiber types include chrysotile and several types of amphiboles, including actinolite, amphibole similar to Libby amphibole, tremolite, and 2 fibers with characteristics that are similar to tremolite/actinolite (solid-solution series).

Shorter fibers (less than 5 microns and greater than 0.5 microns in length, counted with EPASM method) were also detected. The sample with the highest amount of these short fibers was one of the perimeter samples for the child playing scenario in the South Unit, with a concentration of 0.0157 total fibers/cc (Table 4- Appendix C). All of these small fibers had similar dimensions and were all identified as chrysotile fibers. The other perimeter samples and the personal monitor for that sampling event were non-detects.

Activity Reference Samples: To compare activity-based sampling air concentrations with those that would occur under quiescent conditions at the beach without human activity, activity reference samples were taken along the beachfront either before sampling began or at times when activity-based sampling events were not occurring at that location. Asbestos fibers were detected in 2 of the 19 activity reference samples that were analyzed; a short Libby amphibole

fiber in Area 3 of the North Unit (Figure 1) and a PCME chrysotile fiber in Area 13 of the South Unit (Figure 2). Both concentrations were at the lower limit of analytical sensitivity (0.00016 f/cc).

Geographical differences along shoreline- Air and sand samples were collected at locations covering the entire shoreline of IBSP (Figures 1 and 2- Appendix B). Of the 13 samples where asbestos fibers were detected, there does not appear to be any specific pattern to the locations with detections.

Filter over-loading- In the cases where filters were overloaded (#42262 and #42352), co-located filters were available for analysis. Therefore, filter overloading did not result in a loss of exposure information for this study.

Sand Samples: Using the CARB 435 method, all of the 61 sand samples were non-detect for asbestos (analytical sensitivity = 0.25%). This method has received regulatory acceptance for the detection of asbestos fibers in aggregate material (15), and has been used for other bulk material (e.g. soil or sand).

Dust samples: Using the ASTM D5755-03 method, all of the samples were non-detect for asbestos fibers, with a detection limit of 480 s/cm^2 – 980 s/cm^2 .

PUBLIC HEALTH IMPLICATIONS

To evaluate public health hazards associated with environmental contaminants, there needs to be a thorough evaluation of how people may be exposed. For asbestos fibers, the primary pathway for exposure is through inhalation. There is significant uncertainty in assessing health hazards associated with asbestos contamination in bulk material or in environmental media such as soil or sand. Since human exposure occurs as the result of the dispersion of asbestos fibers from the contaminated media into the air, the exposure levels cannot be predicted by only characterizing the asbestos content of the media. Therefore, the primary focus of this assessment has been to evaluate the air concentrations that could occur while people are engaged in typical activities at the beach. This investigation has represented a thorough evaluation of how people using IBSP could be exposed to asbestos fibers through a variety of activities.

EXPOSURE ASSESSMENT

The 2007 USEPA sampling events were designed to reflect the full range of potential activities, including sunbathing, walking, jogging, volleyball, sweeping interior surfaces, and playing in the sand. Some of these activities would occur over a wide area of the beach, while others might involve regular visits to the same general area of the beach. This assessment assumes that visitors could be regular users of IBSP.

Only a limited number of samples had asbestos detections, using either the EPASM or PCME counting criteria. Most of those detections were at the lower limit of sensitivity for the analysis.

To evaluate potential high end exposures, the maximum detected concentrations are used to estimate risk. The highest concentration of EPASM fibers was found in one of the child playing scenarios, with an estimated concentration of 0.016 fibers/cc. However, only 3 out of 154 activity-based samples detected asbestos structures that met the PCME criteria, which serves as the basis for quantitative estimates of cancer risk. The maximum detected concentration of PCME fibers was 0.001 fibers/cc.

HAZARD ASSESSMENT:

Exposure to asbestos has been shown to increase the risk of several health effects, including:

Malignant mesothelioma- Cancer of the membrane lining the chest cavity and covering the lungs (pleura) or lining the abdominal cavity (peritoneum), which can spread to tissues surrounding the lungs or other organs. The great majority of mesothelioma cases are attributable to asbestos exposure (18).

Lung cancer- Cancer of the lung tissue, also known as bronchogenic carcinoma. The combination of tobacco smoking and asbestos exposure greatly increases the risk of developing lung cancer (18).

Laryngeal cancer- Cancer of the epiglottis and vocal cords. Laryngeal cancer arises from the surface epithelium that lines the upper airways, which would be in direct contact with inhaled fibers. A recent Institute of Medicine report concluded that there is sufficient information to infer a causal relationship between asbestos exposure and laryngeal cancer (19)

Noncancer effects- These effects include 1) **asbestosis**, a restrictive lung disease caused by asbestos fibers scarring the lung; 2) **pleural plaques**, localized areas of thickening of the pleura; 3) **diffuse pleural thickening**, generalized thickening of the pleura; 4) **pleural calcification**, calcium deposition on pleural areas thickened from chronic inflammation and scarring; and 5) **pleural effusions**, fluid buildup in the pleural space between the lungs and the chest cavity (18).

The risk of these health effects resulting from the inhalation of asbestos fibers increases with cumulative exposure (that includes the concentration of fibers inhaled, how often and how long the fibers are inhaled), and is also a function of age of first exposure occurred. These effects have mainly been observed in individuals who have had significant levels of exposure, either in the workplace or specific environmental exposures (18).

Ingestion of asbestos causes little or no risk for non-cancer effects. However, some evidence in animal studies exists that acute oral exposure might induce precursor lesions of colon cancer (18). Epidemiological studies of populations who have been exposed to asbestos fibers in drinking water have been inconclusive in associating asbestos ingestion with increased cancer

risk, but some studies have indicated an increased risk for cancer of the stomach, kidney, and pancreas (18).

Fiber length and cancer: There is a significant body of scientific literature demonstrating that the physical dimensions of asbestos fibers are an important indicator of potential toxicity of exposure (20,21,28). PCME fibers are used as the criteria for risk-based evaluations since they are the fiber definitions that were used to characterize asbestos air concentrations in studies of asbestos-related disease from occupational exposures. In response to public concerns about asbestos fiber toxicity from the World Trade Center disaster, ATSDR sponsored an expert panel meeting to review fiber size and its role in fiber toxicity (21). The panel concluded that fiber length plays an important role in toxicity. The role of fiber length appears to be related to the diminished efficiency in clearance of longer fibers by pulmonary macrophages and ciliary action by pulmonary epithelial cells. The ATSDR Expert Panel concluded that fibers greater than 5 microns in length are of a concern for cancer risk, but that fibers with lengths <5 microns are unlikely to cause cancer in humans (21).

Fiber length and other health effects: The potency of asbestos to induce disease generally increases with fiber length. However, asbestos fibers of all lengths induce pathological responses at some level of exposure (22). Factors other than fiber dimensions, such as the ability to generate reactive oxygen species, surface properties, and surface charge, may also play a role in inducing cell damage (22). Experimental studies in laboratory animals have shown that exposure to sufficiently high doses of asbestos fibers can cause inflammation, pulmonary interstitial fibrosis, and pleural reactions. These effects at high dosage levels may be the result of overcoming the ability of the pulmonary system to adequately eliminate the fibers from the respiratory system. However, such effects may not be relevant to human exposures in the environment (21). While short fibers (< 5 microns in length) can penetrate the lower pulmonary system, they are more easily cleared from the lungs by ciliary action of pulmonary epithelial cells and phagocytosis by pulmonary macrophages. These clearance mechanisms move fibers into the upper airways, where they eventually can be expelled, but can also result in the translocation of fibers into the pleura. Therefore, longer fibers are more persistent in the lungs (22).

Fiber mineralogy and toxicity: Based on a wide range of studies, amphibole asbestos appears to be significantly more potent compared to chrysotile in causing mesothelioma and pleural effects and it may also be more potent in causing lung cancer (18,23,24). The differential toxicity may be related to several factors including the higher degree of biopersistence of amphiboles, which is a reflection of both their durability and physiological clearance rate. Animal studies of implantation of asbestos fibers into the pulmonary system have indicated that amphiboles degrade at a slower rate than chrysotile (23,24,25). Experimental studies in baboons have reported a half-life of 90 days for chrysotile fibers in the lungs (26). Support for a greater persistence of amphiboles in humans is provided by an epidemiological study of miners that shows an increasing percentage of amphibole fibers in lung tissue after ceasing work in the mines (27.

Cancer Risk Estimates

Cancer risk is the theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The theoretical cancer risk is calculated using information about the activity patterns that may lead people to be exposed, the concentrations of a contaminant that have been measured, and the known potency of the contaminant to cause cancer. Estimates are made of the amount of time that individuals may be engaged in specific activities at IBSP, which is represented as a time-weighted factor (TWF; Equation 1). Only a few fibers greater than 5 microns in length were found in the activity-based sampling and reference sampling at IBSP. The highest measured concentration of asbestos fibers for any of the simulated activities was 0.001 PCME fibers/cc. This highest concentration was used to quantify the cancer risk, but is likely to result in a significant over-estimate of the actual cancer risk for recreational activity at IBSP.

To calculate the cancer risk, the measured fiber concentration is multiplied by TWF (to represent a lifetime exposure concentration), which is then multiplied by the asbestos Inhalation Unit Risk (IHR) value (Equation 2). Inhalation Unit Risk is a dose-response measure that is expressed as the lifetime cancer risk per concentration unit. It is derived from lifetime tables for assessment of asbestos cancer risk (lung cancer and mesothelioma) using the EPA method (28). To assess the cancer risk for different age groups, less-than-lifetime exposure adjustments were made to the unit risk value [0.23 $(\text{fiber/cc})^{-1}$], as described in the EPA Asbestos Framework document (14) and presented in Appendix D. This adjustment considers factors such as the age at the beginning of exposure and the exposure duration.

Equation 1: Calculation of exposure concentration

$$\text{Time Weighted Factor (TWF)} = \frac{\text{exposure hrs/day}}{24\text{ hrs}} \times \frac{\text{exposure days/yr}}{365\text{ days}}$$

Equation 2: Calculation of lifetime cancer risk

$$\text{Cancer risk} = \text{Fiber concentration} \times \text{TWF} \times \text{Unit risk}^{*}$$

The theoretical cancer risk for recreational users of the beach was calculated for typical (Table 1a) and higher use (Table 1b) activities. The cancer risk is presented for a range of ages for each these activity groups.

Table 1a: Cancer Risk Estimates for Recreational Use of IBSP for Different Ages- average use frequency

Age at beginning of exposure (yrs)	Frequency of exposure		Time weighted factor	Exposure duration (yrs)	Fiber conc. (fibers/cc)+	Unit risk*	Cancer risk
	hrs per day	days per yr					
0	2	25	0.0057	70	0.001	0.23	1.3E-06
5	2	25	0.0057	65	0.001	0.18	1.0E-06
10	2	25	0.0057	60	0.001	0.14	8.0E-07
20	2	25	0.0057	50	0.001	0.087	5.0E-07
30	2	25	0.0057	40	0.001	0.052	3.0E-07

+ Fiber concentration of 0.001 f/cc is maximum concentration detected
* Unit risk adjusted for less than lifetime exposure, based on age at beginning of exposure and exposure duration (see Appendix D).

Table 1b: Cancer Risk Estimates for Recreational Use of IBSP for Different Ages- higher use frequency

Age at beginning of exposure (yrs)	Frequency of exposure		Time weighted factor	Exposure duration (yrs)	Fiber conc (fibers/cc)	Unit risk*	Cancer risk
	hrs per day	days per yr					
0	4	50	0.023	70	0.001	0.23	5.3E-06
5	4	50	0.023	65	0.001	0.18	4.1E-06
10	4	50	0.023	60	0.001	0.14	3.2E-06
20	4	50	0.023	50	0.001	0.087	2.0E-06
30	4	50	0.023	40	0.001	0.052	1.2E-06

+ Fiber concentration of 0.001 f/cc is maximum concentration detected
* Unit risk adjusted for less than lifetime exposure, based on age at beginning of exposure and exposure duration (see Appendix D).

The data in Table 2 summarizes the theoretical cancer risk for the most highly exposed individuals, including children and adults at the beach, joggers/walking who are at the beach daily, and park workers.

Table 2: Cancer Risk Estimates for Various Recreational Activities

	ency of osure		Time weighted factor	Exposure duration (yrs)	Fiber conc (fibers/cc)	Unit risk*	Cancer risk
	hrs per day	days per yr					
Child beach user	4	50	0.023	70	0.001	0.23	5.3E-06
Adult beach user	4	50	0.023	50	0.001	0.087	2.0E-06
Jogger/ walker	1	150	0.017	50	0.001	0.087	1.5E-06
IBSP Worker	8	150	0.14	50	0.001	0.087	1.2E-05

$^{+}$ Fiber concentration of 0.001 f/cc is maximum concentration detected
* Unit risk adjusted for less than lifetime exposure, based on age at beginning of exposure and exposure duration (see Appendix D).

The cancer risks are presented as probabilities, with 1E-06 (10^{-6}) representing an exposure level that would be associated with one excess cancer case among a million exposed individuals. For making risk management decisions, USEPA uses a target cancer risk range 10^{-6} to 10^{-4}. Exposures associated with less than 1E-06 (10^{-6}) cancer risk are considered to be minimal, and those greater than 1E-04 (10^{-4}) require actions be taken to reduce the risk. The cancer risk levels determined for recreational users of IBSP are either below or within this target risk range. It should be noted that since the lifetime exposure concentration was based on the maximum detected concentration of PCME fibers (0.001 f/cc), the actual cancer risk is most likely to be significantly less than estimated.

Uncertainty discussion

The primary focus of the hazard assessment is the calculation of cancer risk for exposure to asbestos fibers through inhalation. The cancer risk assessment methods for asbestos are directed towards relatively long fibers that are greater than 5-10 microns in length. Since most of the fibers detected in the 2007 activity-based samples at IBSP were short fibers (<5 microns in length), their estimated concentration did not influence the estimated cancer risk. However, this does not imply that exposure to short fibers has no risk. Since there are no existing risk assessment methods for quantifying the impact of exposure to short fibers, there is uncertainty about predicting the consequence of exposure for effects other than cancer. Part of the complication in specifically assessing the health impacts of short fibers is the fact that both experimental testing and epidemiologic studies of workers has involved exposure to asbestos fibers that are a mixture of various dimensions. Although a quantitative evaluation of the health risk specifically associated with exposure to short fibers can not be provided, the risk assessment for exposure to long fibers is considered to be a surrogate for the entire range of asbestos fibers that occur in an environmental media. For that reason, the overall assessment of the health risks hazard assessment for longer fibers will be inclusive of even the shorter fibers.

The sample with the highest detection was the perimeter sample (#42259) in the child play scenario at the South Unit. The personal monitor sample, other perimeter samples, and the sand sample were all non-detect for asbestos at that location. The fibers detected in this sample were quite uniform in dimensions and were all relatively short fibers (less than 5 microns in length). This pattern suggests that some asbestos-containing material could have been disturbed during the activity and released fibers that were captured downwind from the activity. While this detection confirms the presence of asbestos fibers on the beach, the infrequency of detections throughout IBSP indicates that this result is not representative of general exposure conditions at IBSP. This observation provides further support for the need to continue the regular beach sweeps to ensure that asbestos-containing material is removed from the beaches.

CHILD HEALTH CONSIDERATIONS

ATSDR recognizes that infants and children may be more vulnerable than adults to exposure in communities faced with environmental contamination. Because children depend completely on adults for risk identification and management decisions, ATSDR is committed to evaluating their special interests.

The effects of asbestos on children are thought to be similar to the effects on adults. However, children could be especially vulnerable to asbestos exposures due to the following factors.

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

The evaluation of potential exposure to children was included in the sampling strategy and in the assessment of potential health hazard. Therefore, the conclusions stated below are inclusive of considerations for children who are engaged in recreational activities at IBSP.

CONCLUSIONS

A number of potential sources of asbestos-containing material may have affected IBSP over the past several decades, including building and infrastructure materials from former beachfront homes that were located on what is now IBSP property and the North Point Marina and the placement of feeder sands on the north end of IBSP. That ACM is still washing up onshore at IBSP indicates that source material is still in the lake. However, three prior investigations have evaluated asbestos contamination at IBSP, using different sampling and analytical methods. All of these investigations concluded that the conditions at IBSP do not pose a public health hazard. The focus of this document is to consider these past investigations and to evaluate further the USEPA activity-based sampling data collected in September, 2007. Considering all of the available information about the presence of asbestos at ISBP, ATSDR concludes that *recreational use of the beach is not expected to harm people's health*. This conclusion is based on the fact that very low levels of asbestos fibers were detected with extensive sampling that

directly evaluated how people could be exposed. The conclusion of this assessment is also consistent with those of previous investigations.

RECOMMENDATIONS

1) IDNR should continue regular beach sweeps to remove ACM that washes up on shore at IBSP. These sweeps should continue until ACM is no longer found at IBSP.

2) The asbestos material that has been collected along the shoreline is not generally in a condition that would release fibers and result in an exposure. However, as a precautionary measure, the IDNR should continue to provide IBSP users with visual and written information alerting them to the presence of ACM on the beach. IBSP users should report the location of specific areas where ACM is found to IBSP staff. Individuals should not disturb ACM or attempt to discard this material on their own.

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APPENDIX A: Glossary

ABS	**Activity-based sampling:** A field sampling approach in which airborne concentrations of asbestos are directly measured, under condition where the potential source material (soil or dust) is disturbed.
ACM	**Asbestos Containing Material**
Actinolite	A mineral in the amphibole group that can exhibit an asbestiform habit. Actinolite asbestos is generally not used commercially, but is a common impurity in chrysotile asbestos.
AHERA	**Asbestos Hazard Emergency Response Act of 1986:** In 1986, the Asbestos Hazard Emergency Response Act (AHERA) was signed into law as Title II of the Toxic Substance Control Act. Additionally, the Asbestos School Hazard Abatement Reauthorization Act (ASHARA), passed in 1990, requires accreditation of personnel working on asbestos activities in schools, and public and commercial buildings. See applicability discussion (Section 2).
Amosite	A type of asbestos in the amphibole group; it is also known as brown asbestos.
Amphibole	A group of double chain silicate minerals, which may occur in an asbestiform habit. Examples of regulated amphiboles include crocidolite, anthophyllite, tremolite, actinolite, and amosite.
Analytical sensitivity	The sample-specific lowest concentration of asbestos the laboratory can detect for a given method.
Asbestiform	Characteristics of fibrous minerals giving them the properties of commercial asbestos (e.g., flexibility, high tensile strength, or long, thin fibers occurring in bundles).
Asbestos	The generic name used for a group of naturally occurring mineral silicate fibers of the serpentine and amphibole series, displaying similar physical characteristics although differing in composition.
Asbestosis	A non-cancerous disease associated with inhalation of asbestos fibers and characterized by scarring of the air-exchange regions of the lungs
Aspect ratio	Length to width ratio of a particle or fiber.
ASTM	**American Society for Testing and Materials:** A international voluntary standards development organizations that provides technical standards for materials, products, systems, and services.
ATSDR	**Agency for Toxic Substances and Disease Registry:** A federal public health agency within the U.S. Department of Health and Human Services, and associated with the Centers for Disease Control and Prevention. ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. (http://www.atsdr.cdc.gov/)
Bulk sample	A sample of suspected media (e.g., soil or dust) is obtained from a site to be analyzed microscopically for asbestos content. Bulk sample analysis can be part of a process to assess the hazard from asbestos at a site.
CARB 435	**California Air Resources Board analytical method 435** A specialized polarized light microscopy (PLM) method for testing asbestos content of serpentine aggregate and frequently used to determine asbestos content in other bulk materials. The method includes reporting the asbestos content by performing a 400 point count technique which has a detection limit of 0.25%.
Carcinogen	Any substance that causes cancer.
Chrysotile	An asbestiform member of the serpentine group of minerals. It is the most common form of asbestos used commercially and is also referred to as white asbestos.

Detection limit	The minimum concentration of an analyte in a sample, that with a high level of confidence is not zero.
Direct preparation	In direct preparation, the fibers on the filter are examined by electron microscopy directly after processing.. This is In contrast to indirect preparation, where a filter with too much material undergoes a separation step (commonly dispersion in water) to allow for analysis.
DQO	**Data Quality Objectives**
ED	**Electron diffraction** A specialized technique used to study matter by firing electrons at a sample and observing the resulting interference pattern.
EDS	**Energy Dispersive Spectroscopy**
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].
f/cc	**Fibers per cubic centimeter**. Units of air concentration of asbestos fibers.
Friable	Material that, when dry, can be crumbled, pulverized or reduced to powder by hand pressure
GOs	**Grid openings.** The field of examination for asbestos fibers under the electron microscope.
IRIS	**Integrated Risk Information System-** USEPA database of chemical and fiber toxicity information that is used to support the risk assessment process. (http://www.epa.gov/iris
ISO 10312	**International Organization for Standardization Method 10312** A reference method using transmission electron microscopy for the determination of the concentration of asbestos structures in ambient atmospheres and includes measurement of the lengths, widths and aspect ratios of the asbestos structures. The method allows determination of the types of asbestos fibers present.
IUR	**Inhalation unit risk** Risk per concentration unit for a lifetime of continuous exposure. For asbestos, it is the inhalation risk associated with a specific concentration in fibers per cubic centimeter of air (f/cc).
MCE	**Mixed cellulose ester-** A type of filter used to collect particulates and fibers for air sampling.
Mesothelioma	A malignant tumor of the covering of the lung or the lining of the pleural and abdominal cavity often associated with exposure to asbestos.
Microvacuum samples	A microvacuum sample, collected using the method ASTM D5755, is similar to a wipe sample with the exception that a predefined area is "vacuumed" using a high-volume air pump equipped with a sample cassette that contains a cellulose filter instead of wiping with a wet wipe.
NIOSH	**National Institute for Occupational Safety and Health** The National Institute for Occupational Safety and Health (NIOSH) is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH is part of the Centers for Disease Control and Prevention in the Department of Health and Human Services.
NIOSH 7400	A light microscopy analytical method, also known as NIOSH Phase Contrast Microscopy [PCM] Method 7400.

NIOSH 9002	A polarized light microscopy (PLM) analytical method useful for the qualitative identification of asbestos and the semi-quantitative determination of asbestos content of bulk samples. The method measures percent asbestos as perceived by the analyst in comparison to standard area projections, photos, and drawings, or trained experience. The method is not applicable to samples containing large amounts of fine fibers below the resolution of the light microscope.
PCM	**Phase contrast microscopy** A light-enhancing microscope technology that employs an optical mechanism to translate small variations in phase into corresponding changes in amplitude, resulting in high-contrast images. This method is used to measure airborne fibers in occupational environments; however, it cannot differentiate asbestos fibers from other fibers.
PCMe	**PCM-equivalent** This refers to chrysotile and amphibole structures identified through transmission electron microscopy (TEM) analysis that are equivalent to those that would be identified in the same sample through phase contrast microscopy analysis, with the main difference being that TEM additionally permits the specific identification of asbestos fibers. PCMe structures are structures with asbestos chemical composition greater than 5 microns in length, between 0.25 and 3 microns wide, and having at least a 3 to 1 length to width (aspect) ratio.
Personal air monitor	Also known as a low-flow or low-volume sample pump, this is an air sample pump that is portable so that it can be worn by a member of the sampling team during activity based sample collection. The air flow for a personal sample pump is typically 1 to 10 liters per minute.
Pulmonary fibrosis	The development of fibrotic tissue in the lung, which can occur as a result of asbestos exposure.
PLM	**Polarized light microscopy** A microscope technology that uses the polarity (or orientation) of light waves to provide better images than a standard optical microscope. This microscope can identify asbestos mineral types.
QAPP	**Quality Assurance Project Plan** The USEPA has developed the QAPP as a tool for project managers and planners to document the type and quality of data needed for environmental decisions and to describe the methods for collecting and assessing those data. The development, review, approval, and implementation of the QAPP is part of USEPA's mandatory Quality System.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
s/cc	Structures per cubic centimeter. Units of measurement for asbestos bundles, matrices, clusters, etc. in air.
SAP	**Sampling and Analysis Plan** A plan intended assist organization in documenting the procedural and analytical requirements for a one-time or time-limited project involving the collection of water, soil, sediment, or biological samples taken to characterize areas of potential environmental contamination. It combines, in a short form, the basic elements of a Quality Assurance Project Plan (QAPP) and a Field Sampling Plan (FSP).
Serpentine	A name given to several members of a polymorphic group of magnesium silicate minerals—those having essentially the same chemistry but different structures or forms. Chrysotile asbestos is the fibrous member of the serpentine group.
SOP	**Standard operating procedure**

Stationary air monitor	An air sample monitor that is placed in a single location and is not moved during one or more sampling events.
TEM	**Transmission electron microscopy** A microscope technology and an analytical method to identify and count the number of asbestos fibers present in a sample. It uses the properties of electrons to provide more detailed images than polarized light microscopy (PLM). TEM is capable of achieving a magnification of 20,000x.
Tremolite	A mineral in the amphibole group, that occurs as a series in which magnesium and iron can freely substitute for each other and may occur in an asbestiform habit. Tremolite is the mineral when magnesium is predominant; otherwise, the mineral is actinolite. Tremolite asbestos is not commonly used commercially but it is often present in chrysotile formations and may contaminate mined chrysotile.
TWF	**Time Weighting Factor** This factor accounts for less-than-continuous exposure during a year.

APPENDIX B: Figures

Figure 1: Overview of Air Sampling Locations-North Unit

Figure 2: Overview of Air Sampling Locations-South Unit

APPENDIX C: Data Tables and Figure

Table 3: Activity-Based and Reference Sampling Results

Activity	Number of Samples	Maximum detection limit (s/cc)[6]	PCME fibers[7]		EPASM fibers [8]		Mineral Type[9]
			Samples with fiber detections	Maximum estimated concentration (s/cc)	Samples with fiber detections	Maximum estimated concentration (s/cc)	
Reference Samples	47	0.00017	0	ND	4	0.00017	CH, LA , AC
ATV Riding Perimeter	31	0.001	1	0.0009	2	0.002	CH, LA
ATV Riding Personal	9	0.001	0	ND	0	ND	
Child Playing- Perimeter	20	0.001	1	0.001	2	0.016	CH, AC
Child Playing- Personal	7	0.001	1	0.001	2	0.001	TR/AC
Jogging Perimeter	19	0.001	0	ND	0	ND	
Jogging Personal	4	0.001	0	ND	1	0.001	CH
Raking Perimeter	20	0.001	0	ND	0	ND	
Raking Personal	6	0.001	0	ND	0	ND	
Soccer Perimeter	8	0.001	0	ND	1	0.001	CH
Soccer Personal	6	0.001	0	ND	0	ND	
Sunbather Personal	5	0.001	0	ND	0	ND	
Sweeping Inside Buildings	5	0.001	0	ND	1	ND	
Volleyball Perimeter	6	0.001	0	ND	0	ND	
Volleyball Personal	8	0.001	0	ND	0	ND	
Total	**201**		**3**		**13**		

6 s/cc: asbestos structures per cubic centimeter of air

7 PCME (Phase Contrast Microscopy Equivalent structure): fiber length greater than 5.0 microns; aspect ratio greater than 3:1, and width greater than 0.25 microns

8 EPASM (EPA Superfund Method structure): fiber length greater than 0.5 microns and aspect ratio greater than 3:1

9 CH = Chrysotile; AC = Actinolite; LA = similar to Libby Amphibole; Trem/Act = Solution Series: Tremolite-Actinolite

Table 4: **Summary of Detected Structures in Air Samples**

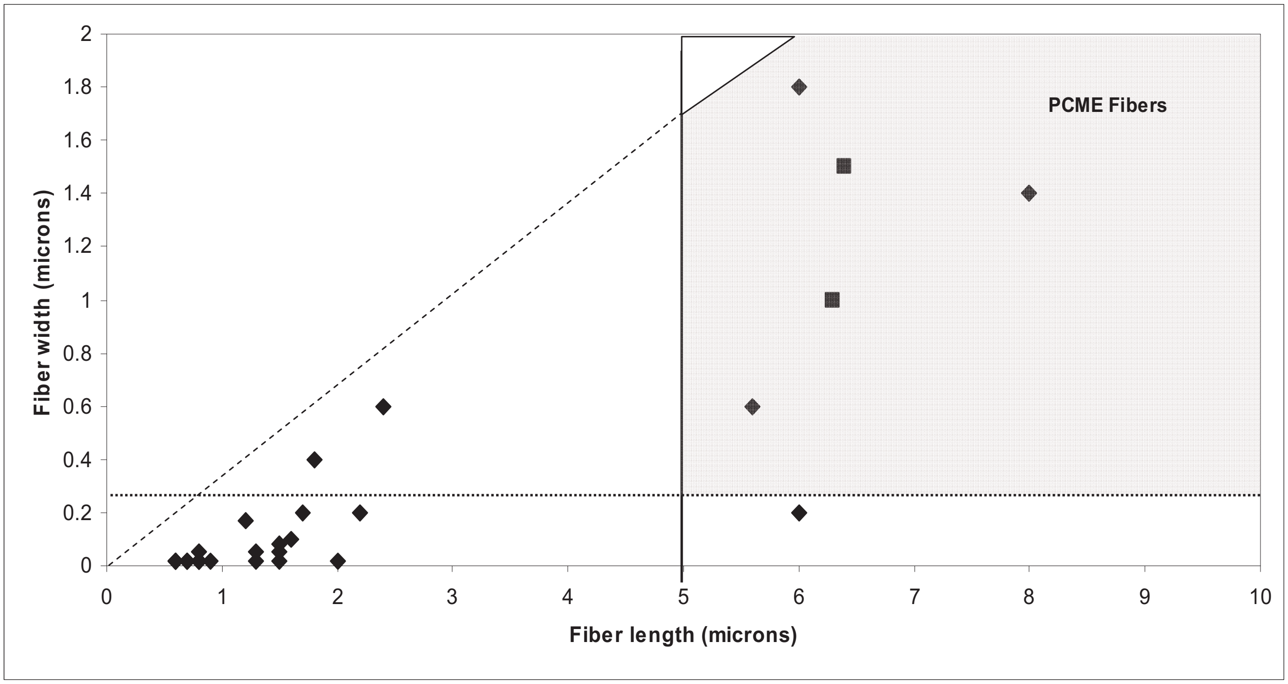
Sample number	Activity and location	Structure dimensions[a]		Aspect ratio[b]	Mineral Type[c]
		Length (μ)	Width (μ)		
42190	Reference- Area 13	6	0.2	30.0	CH
42197	Reference- Area 3 #2	1.7	0.2	8.5	LA
42209	Reference- Nature Center- #1 (day 2)	1.8	0.4	4.5	LA
42232	ATV riding-South Area 21 perimeter #4	1.5	0.05	30.0	CH
		1.5	0.08	18.8	CH
		6.4	1.5	4.3	NAM
42245	Reference- Nature Center #1 (day 3)	2.2	0.2	11.0	AC
42247	Child Play- North	**6**	**1.8**	**3.3**	**AC**
42249	Child Play- North; perimeter sample	**5.6**	**0.6**	**9.3**	**AC**
42259	Child Play- South; perimeter sample	0.8	0.02	40.0	CH
		0.9	0.02	45.0	CH
		2	0.02	100.0	CH
		1.3	0.02	65.0	CH
		0.7	0.02	35.0	CH
		0.6	0.02	30.0	CH
		0.6	0.02	30.0	CH
		0.7	0.02	35.0	CH
		0.6	0.02	30.0	CH
		0.8	0.02	40.0	CH
		0.7	0.02	35.0	CH
		0.8	0.02	40.0	CH
		0.6	0.02	30.0	CH
		0.8	0.02	40.0	CH
		1.5	0.02	75.0	CH
		1.3	0.05	26.0	CH
42264	Child Play-South	1.2	0.17	7.1	Trem-Act
44271	Sweep IBSP office	2.4	0.6	4.0	Trem-Act
		6.3	1	6.3	NAM
42381	ATV riding- South; perimeter sample #5	**8**	**1.4**	**5.7**	**LA**
42391	Soccer-North; perimeter sample	1.6	0.1	16.0	CH
42406	Jogging- South	0.8	0.05	16.0	CH

[a] Structures meeting definition of PCME fiber shown in bold (fiber length greater than 5.0 microns; aspect ratio greater than 3:1, and width greater than 0.25 microns)

[b] Aspect ratio: ratio of structure length to width

[c] Mineral type: AC = actinolite; CH = chrysotile; LA = Libby amphibole; TR = tremolite; Trem-Act = Solid solution series: Tremolite-Actinolite; NAM = non-asbestos material

Figure 3: Dimensions of fibers detected in analysis of IBSP samples



Shaded area represents the dimensional criteria for PCME fibers: length greater than 5 microns (solid black line), width greater than 0.25 microns (dotted line), and aspect ratio greater than 3:1 (dashed line). Fibers identified as either asbestos (◆) or non-asbestos (■).

APPENDIX D: Extrapolated Unit Risk Values for Continuous and Less-Than-Lifetime Exposures (PCM f/cc) (from Reference 14)

Age at Onset	Exposure Duration (years)																	
	1	2	3	4	5	6	8	10	12	14	16	20	24	25	30	40	50	60	LT
0	1.0E-02	2.0E-02	3.0E-02	3.9E-02	4.7E-02	5.5E-02	7.1E-02	8.5E-02	9.8E-02	1.1E-01	1.2E-01	1.4E-01	1.5E-01	1.6E-01	1.7E-01	1.9E-01	2.1E-01	2.2E-01	2.3E-01
1	9.9E-03	1.9E-02	2.8E-02	3.7E-02	4.5E-02	5.3E-02	6.8E-02	8.1E-02	9.4E-02	1.0E-01	1.2E-01	1.3E-01	1.5E-01	1.5E-01	1.7E-01	1.9E-01	2.0E-01	2.1E-01	2.2E-01
2	9.6E-03	1.9E-02	2.7E-02	3.6E-02	4.4E-02	5.1E-02	6.5E-02	7.8E-02	9.0E-02	1.0E-01	1.1E-01	1.3E-01	1.4E-01	1.5E-01	1.6E-01	1.8E-01	1.9E-01	2.0E-01	2.1E-01
3	9.2E-03	1.8E-02	2.6E-02	3.4E-02	4.2E-02	4.9E-02	6.3E-02	7.5E-02	8.7E-02	9.7E-02	1.1E-01	1.2E-01	1.4E-01	1.4E-01	1.5E-01	1.7E-01	1.8E-01	1.9E-01	2.0E-01
4	8.8E-03	1.7E-02	2.5E-02	3.3E-02	4.0E-02	4.7E-02	6.0E-02	7.2E-02	8.3E-02	9.3E-02	1.0E-01	1.2E-01	1.3E-01	1.3E-01	1.5E-01	1.6E-01	1.8E-01	1.8E-01	1.9E-01
5	8.5E-03	1.7E-02	2.4E-02	3.2E-02	3.9E-02	4.6E-02	5.8E-02	7.0E-02	8.0E-02	8.9E-02	9.8E-02	1.1E-01	1.3E-01	1.3E-01	1.4E-01	1.6E-01	1.7E-01	1.7E-01	1.9E-01
6	8.2E-03	1.6E-02	2.3E-02	3.1E-02	3.7E-02	4.4E-02	5.6E-02	6.7E-02	7.7E-02	8.6E-02	9.4E-02	1.1E-01	1.2E-01	1.2E-01	1.3E-01	1.5E-01	1.6E-01	1.7E-01	1.8E-01
7	7.9E-03	1.5E-02	2.3E-02	2.9E-02	3.6E-02	4.2E-02	5.4E-02	6.4E-02	7.4E-02	8.3E-02	9.1E-02	1.0E-01	1.2E-01	1.2E-01	1.3E-01	1.4E-01	1.5E-01	1.6E-01	1.7E-01
8	7.6E-03	1.5E-02	2.2E-02	2.8E-02	3.5E-02	4.1E-02	5.2E-02	6.2E-02	7.1E-02	7.9E-02	8.7E-02	1.0E-01	1.1E-01	1.1E-01	1.2E-01	1.4E-01	1.5E-01	1.5E-01	1.6E-01
9	7.3E-03	1.4E-02	2.1E-02	2.7E-02	3.3E-02	3.9E-02	5.0E-02	5.9E-02	6.8E-02	7.6E-02	8.4E-02	9.6E-02	1.1E-01	1.1E-01	1.2E-01	1.3E-01	1.4E-01	1.5E-01	1.6E-01
10	7.0E-03	1.4E-02	2.0E-02	2.6E-02	3.2E-02	3.8E-02	4.8E-02	5.7E-02	6.6E-02	7.3E-02	8.0E-02	9.2E-02	1.0E-01	1.0E-01	1.1E-01	1.3E-01	1.4E-01	1.4E-01	1.5E-01
11	6.8E-03	1.3E-02	1.9E-02	2.5E-02	3.1E-02	3.6E-02	4.6E-02	5.5E-02	6.3E-02	7.1E-02	7.7E-02	8.9E-02	9.8E-02	1.0E-01	1.1E-01	1.2E-01	1.3E-01	1.3E-01	1.4E-01
12	6.5E-03	1.3E-02	1.9E-02	2.4E-02	3.0E-02	3.5E-02	4.4E-02	5.3E-02	6.1E-02	6.8E-02	7.4E-02	8.5E-02	9.4E-02	9.6E-02	1.0E-01	1.2E-01	1.2E-01	1.3E-01	1.4E-01
13	6.3E-03	1.2E-02	1.8E-02	2.3E-02	2.9E-02	3.4E-02	4.3E-02	5.1E-02	5.8E-02	6.5E-02	7.1E-02	8.2E-02	9.1E-02	9.2E-02	1.0E-01	1.1E-01	1.2E-01	1.2E-01	1.3E-01
14	6.1E-03	1.2E-02	1.7E-02	2.3E-02	2.8E-02	3.2E-02	4.1E-02	4.9E-02	5.6E-02	6.3E-02	6.8E-02	7.9E-02	8.7E-02	8.9E-02	9.7E-02	1.1E-01	1.1E-01	1.2E-01	1.2E-01
15	5.9E-03	1.1E-02	1.7E-02	2.2E-02	2.7E-02	3.1E-02	3.9E-02	4.7E-02	5.4E-02	6.0E-02	6.6E-02	7.5E-02	8.3E-02	8.5E-02	9.3E-02	1.0E-01	1.1E-01	1.1E-01	1.2E-01
16	5.6E-03	1.1E-02	1.6E-02	2.1E-02	2.6E-02	3.0E-02	3.8E-02	4.5E-02	5.2E-02	5.8E-02	6.3E-02	7.2E-02	8.0E-02	8.2E-02	8.9E-02	9.8E-02	1.0E-01	1.1E-01	1.1E-01
17	5.4E-03	1.1E-02	1.6E-02	2.0E-02	2.5E-02	2.9E-02	3.7E-02	4.4E-02	5.0E-02	5.6E-02	6.1E-02	7.0E-02	7.7E-02	7.8E-02	8.5E-02	9.4E-02	1.0E-01	1.0E-01	1.1E-01
18	5.2E-03	1.0E-02	1.5E-02	1.9E-02	2.4E-02	2.8E-02	3.5E-02	4.2E-02	4.8E-02	5.3E-02	5.8E-02	6.7E-02	7.4E-02	7.5E-02	8.1E-02	9.0E-02	9.5E-02	9.8E-02	1.0E-01
19	5.1E-03	9.9E-03	1.4E-02	1.9E-02	2.3E-02	2.7E-02	3.4E-02	4.0E-02	4.6E-02	5.1E-02	5.6E-02	6.4E-02	7.1E-02	7.2E-02	7.8E-02	8.6E-02	9.1E-02	9.4E-02	9.8E-02
20	4.9E-03	9.5E-03	1.4E-02	1.8E-02	2.2E-02	2.6E-02	3.3E-02	3.9E-02	4.4E-02	4.9E-02	5.4E-02	6.2E-02	6.8E-02	6.9E-02	7.5E-02	8.3E-02	8.7E-02	9.0E-02	9.3E-02
21	4.7E-03	9.2E-03	1.3E-02	1.7E-02	2.1E-02	2.5E-02	3.1E-02	3.7E-02	4.3E-02	4.7E-02	5.2E-02	5.9E-02	6.5E-02	6.6E-02	7.2E-02	7.9E-02	8.3E-02	8.6E-02	8.9E-02
22	4.5E-03	8.8E-03	1.3E-02	1.7E-02	2.0E-02	2.4E-02	3.0E-02	3.6E-02	4.1E-02	4.6E-02	5.0E-02	5.7E-02	6.2E-02	6.3E-02	6.9E-02	7.6E-02	8.0E-02	8.2E-02	8.5E-02
23	4.4E-03	8.5E-03	1.2E-02	1.6E-02	2.0E-02	2.3E-02	2.9E-02	3.5E-02	3.9E-02	4.4E-02	4.8E-02	5.4E-02	6.0E-02	6.1E-02	6.6E-02	7.2E-02	7.6E-02	7.8E-02	8.1E-02
24	4.2E-03	8.2E-03	1.2E-02	1.6E-02	1.9E-02	2.2E-02	2.8E-02	3.3E-02	3.8E-02	4.2E-02	4.6E-02	5.2E-02	5.7E-02	5.8E-02	6.3E-02	6.9E-02	7.2E-02	7.4E-02	7.7E-02
25	4.1E-03	7.9E-03	1.2E-02	1.5E-02	1.8E-02	2.1E-02	2.7E-02	3.2E-02	3.6E-02	4.0E-02	4.4E-02	5.0E-02	5.5E-02	5.6E-02	6.0E-02	6.6E-02	6.9E-02	7.1E-02	7.3E-02
26	3.9E-03	7.7E-03	1.1E-02	1.4E-02	1.8E-02	2.1E-02	2.6E-02	3.1E-02	3.5E-02	3.9E-02	4.2E-02	4.8E-02	5.2E-02	5.3E-02	5.8E-02	6.3E-02	6.6E-02	6.8E-02	7.0E-02
27	3.8E-03	7.4E-03	1.1E-02	1.4E-02	1.7E-02	2.0E-02	2.5E-02	3.0E-02	3.4E-02	3.7E-02	4.1E-02	4.6E-02	5.0E-02	5.1E-02	5.5E-02	6.0E-02	6.3E-02	6.4E-02	6.6E-02
28	3.7E-03	7.1E-03	1.0E-02	1.3E-02	1.6E-02	1.9E-02	2.4E-02	2.8E-02	3.2E-02	3.6E-02	3.9E-02	4.4E-02	4.8E-02	4.9E-02	5.3E-02	5.7E-02	6.0E-02	6.1E-02	6.3E-02
29	3.5E-03	6.9E-03	1.0E-02	1.3E-02	1.6E-02	1.8E-02	2.3E-02	2.7E-02	3.1E-02	3.4E-02	3.7E-02	4.2E-02	4.6E-02	4.7E-02	5.0E-02	5.5E-02	5.7E-02	5.8E-02	6.0E-02
30	3.4E-03	6.6E-03	9.7E-03	1.2E-02	1.5E-02	1.8E-02	2.2E-02	2.6E-02	3.0E-02	3.3E-02	3.6E-02	4.0E-02	4.4E-02	4.5E-02	4.8E-02	5.2E-02	5.4E-02	5.5E-02	5.7E-02
31	3.3E-03	6.4E-03	9.3E-03	1.2E-02	1.5E-02	1.7E-02	2.1E-02	2.5E-02	2.9E-02	3.2E-02	3.4E-02	3.9E-02	4.2E-02	4.3E-02	4.6E-02	4.9E-02	5.1E-02	5.3E-02	5.4E-02
32	3.2E-03	6.2E-03	9.0E-03	1.2E-02	1.4E-02	1.6E-02	2.1E-02	2.4E-02	2.7E-02	3.0E-02	3.3E-02	3.7E-02	4.0E-02	4.1E-02	4.4E-02	4.7E-02	4.9E-02	5.0E-02	5.1E-02
33	3.1E-03	6.0E-03	8.7E-03	1.1E-02	1.4E-02	1.6E-02	2.0E-02	2.3E-02	2.6E-02	2.9E-02	3.1E-02	3.5E-02	3.8E-02	3.9E-02	4.2E-02	4.5E-02	4.6E-02	4.7E-02	4.8E-02
34	3.0E-03	5.7E-03	8.3E-03	1.1E-02	1.3E-02	1.5E-02	1.9E-02	2.2E-02	2.5E-02	2.8E-02	3.0E-02	3.4E-02	3.7E-02	3.7E-02	4.0E-02	4.2E-02	4.4E-02	4.5E-02	4.6E-02
35	2.9E-03	5.5E-03	8.0E-03	1.0E-02	1.3E-02	1.5E-02	1.8E-02	2.1E-02	2.4E-02	2.7E-02	2.9E-02	3.2E-02	3.5E-02	3.5E-02	3.8E-02	4.0E-02	4.2E-02	4.2E-02	4.3E-02
36	2.8E-03	5.3E-03	7.7E-03	1.0E-02	1.2E-02	1.4E-02	1.8E-02	2.1E-02	2.3E-02	2.5E-02	2.7E-02	3.1E-02	3.3E-02	3.4E-02	3.6E-02	3.8E-02	3.9E-02	4.0E-02	4.1E-02
37	2.7E-03	5.1E-03	7.5E-03	9.6E-03	1.2E-02	1.3E-02	1.7E-02	2.0E-02	2.2E-02	2.4E-02	2.6E-02	2.9E-02	3.2E-02	3.2E-02	3.4E-02	3.6E-02	3.7E-02	3.8E-02	3.8E-02
38	2.6E-03	5.0E-03	7.2E-03	9.2E-03	1.1E-02	1.3E-02	1.6E-02	1.9E-02	2.1E-02	2.3E-02	2.5E-02	2.8E-02	3.0E-02	3.0E-02	3.2E-02	3.4E-02	3.5E-02	3.6E-02	3.6E-02
39	2.5E-03	4.8E-03	6.9E-03	8.9E-03	1.1E-02	1.2E-02	1.5E-02	1.8E-02	2.0E-02	2.2E-02	2.4E-02	2.7E-02	2.8E-02	2.9E-02	3.0E-02	3.2E-02	3.3E-02	3.4E-02	3.4E-02
40	2.4E-03	4.6E-03	6.6E-03	8.5E-03	1.0E-02	1.2E-02	1.5E-02	1.7E-02	1.9E-02	2.1E-02	2.3E-02	2.5E-02	2.7E-02	2.7E-02	2.9E-02	3.1E-02	3.1E-02	3.2E-02	3.2E-02
45	1.9E-03	3.7E-03	5.4E-03	6.9E-03	8.2E-03	9.5E-03	1.2E-02	1.3E-02	1.5E-02	1.6E-02	1.7E-02	1.9E-02	2.0E-02	2.0E-02	2.1E-02	2.2E-02	2.3E-02	2.3E-02	2.3E-02
50	1.5E-03	2.9E-03	4.1E-03	5.3E-03	6.3E-03	7.2E-03	8.7E-03	1.0E-02	1.1E-02	1.2E-02	1.3E-02	1.4E-02	1.4E-02	1.4E-02	1.5E-02	1.5E-02	1.5E-02	1.5E-02	1.6E-02