Health Consultation

PUBLIC COMMENT VERSION

Evaluation of Community-Wide Asbestos Exposures

EL DORADO HILLS NATURALLY OCCURRING ASBESTOS SITE
EL DORADO HILLS BOULEVARD, EL DORADO HILLS, CALIFORNIA

EPA FACILITY ID: CAN000906083

MARCH 29, 2010

COMMENT PERIOD ENDS: JUNE 30, 2010

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

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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Prepared By:

U.S. Department of Health and Human Services
Public Health Service
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Table of Contents

Summary

Introduction

ATSDR's top priority is to ensure that people living in the El Dorado Hills area have the best information possible to safeguard their health.

ATSDR conducted this health consultation in response to concerns about potential community exposures to naturally occurring asbestos (NOA) deposits in local soil and rock formations. Sampling conducted by the U.S. Environmental Protection Agency (EPA) had previously shown that people performing typical outdoor recreational activities could breathe in high levels of NOA, compared to reference samples. Community members asked ATSDR what this finding meant to their health and what they should do to protect their health.

To answer these questions for the community as a whole, ATSDR used the EPA sampling results to estimate how much NOA an El Dorado Hills resident might breathe in throughout life. Several different risk assessment calculation methods were then compared to get a general sense of the risk of developing asbestos-related cancers from those exposures. Finally, results of additional studies on NOA in the El Dorado Hills area were examined.

Conclusions ATSDR reached 2 important conclusions in the health consultation:

Conclusion 1 Breathing in naturally occurring asbestos (NOA) in the El Dorado Hills area, over a lifetime, has the potential to harm people's health.

Basis for conclusion

- Background levels of NOA in El Dorado Hills are higher than asbestos levels measured in other non-urban and most urban environments. Activities that disturb NOA could result in levels higher than background.
- A general sense of the increased risk of developing cancer from breathing in asbestos throughout life was obtained using several different risk assessment methods with the results of EPA's activity based sampling in El Dorado Hills. For each method, a range of theoretical increased risks of developing cancer was estimated using different assumptions about how much and how often people breathed in NOA. Each risk method has considerable uncertainty, but the different risk methods gave similar results: the predicted increased risk of cancer ranged from too low to be of concern to a level high enough that action to prevent exposures would be warranted.
- Any one person could have markedly higher (or lower) exposures than the general estimates made in this report, depending on whether, how, and how often they encounter NOA in their daily activities.

Next steps The following actions will reduce the likelihood for people to breathe NOA:

Increase Awareness

- El Dorado County should continue to assess the community's knowledge about the presence and associated risk of NOA and to provide information about ways to manage the risk. ATSDR can provide assistance, if requested.
- El Dorado County should implement, to the extent possible, effective ways to:
  - Maintain current records of locations known to contain NOA and
  - Notify current and prospective landowners of the possibility for NOA to exist in soil or bedrock on their property.

Limit Exposure

- State and local entities should continue to enforce applicable dust regulations throughout the community, which will reduce releases of NOA. For sites subject to asbestos hazard mitigation requirements, these regulations involve:
  - Prohibition of visible dust emissions outside the property line or more than 25 feet from the point of dust-disturbing activities,
  - Implementation of procedures to prevent vehicles and equipment from releasing dust or tracking soil off-site, and
  - Requirements for planning, notification, and record-keeping.
- Community members and groups should learn how to minimize their exposure to NOA while conducting their normal activities. ATSDR guidelines are included in Appendix H of this report.

Conclusion 2 A health study of the community of El Dorado Hills would not provide helpful information at this time.

Basis for conclusion

- It is very unlikely that a health study would provide additional information not already known about the presence of NOA or potential health risks from inhaling NOA:
  - Although theoretical risk was increased, potential exposures are generally orders of magnitude lower than those experienced by former asbestos workers. Potential exposures are also lower than what limited exposure studies have suggested are present in other NOA communities where disease was found. Therefore, we anticipate there would be very few cases of disease, if any, and the findings may not be generalizable to the community as a whole.
  - There is currently no reliable way to measure a particular person's exposure.
  - Even if exposures were high enough to cause disease, it takes decades for symptoms to appear. Therefore health conditions may not be detected at this time.
- A health study would not conclusively state that NOA caused a specific person's health condition.

Next Steps

- Although we do not expect observable increases in disease, state authorities should continue to monitor asbestos-related cancer incidence rates in the area as a means to monitor the community's health and to identify any unforeseen elevation.
- If community members feel their health has been affected by NOA, they should consult with their personal medical provider.
- ATSDR encourages further research on NOA exposures and community health by governmental and academic organizations. ATSDR may refine the conclusions and recommendations of this health consultation as results of ongoing asbestos research become available.

For More Information For further information about this health consultation, please call ATSDR at 1-800-CDC-INFO and ask for information about the "El Dorado Hills Naturally Occurring Asbestos" site. If you have concerns about your health, you should contact your health care provider.

Background

El Dorado Hills is a community located on the western side of El Dorado County, about 20 miles east of Sacramento, California. The area around El Dorado Hills has been the subject of attention in recent years due to natural deposits of asbestos minerals in local soils and rock formations and concern about potential human exposure to asbestos resulting from disturbance of the deposits. The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated potential exposures to students and staff at a high school in El Dorado Hills and published a health consultation in 2006. As an outcome of that evaluation and remaining questions about risk in the community as a whole, ATSDR undertook further review of data collected by the U.S. Environmental Protection Agency (EPA) and others at other El Dorado Hills locations. This health consultation summarizes those data, describes additional data analysis that ATSDR funded to obtain more detailed results from earlier sampling, and describes the methods used to determine the likelihood of general community exposures leading to adverse health effects.

Peer Review

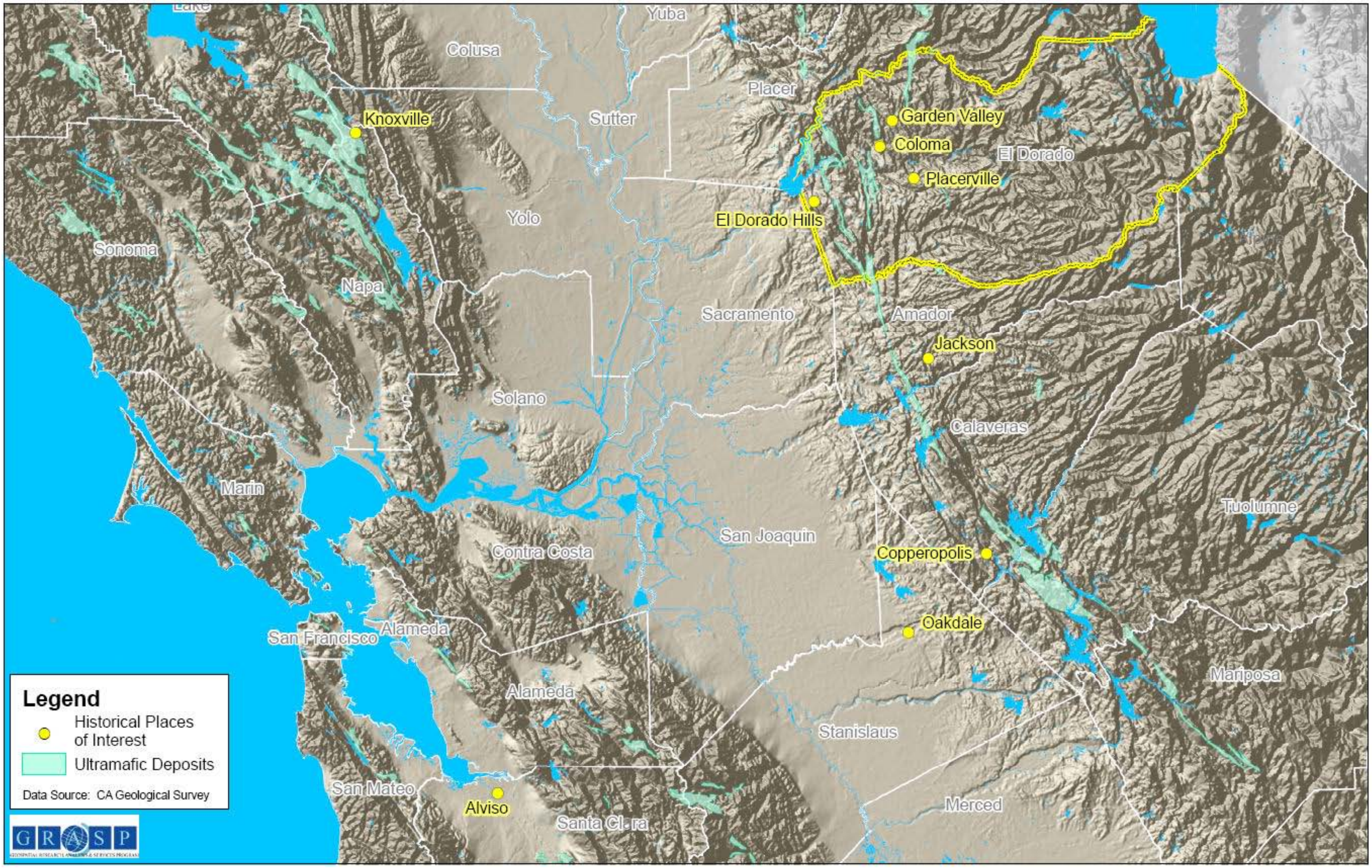
Many issues in asbestos science are currently debated among scientists. ATSDR requested a draft of this public health consultation be "peer reviewed" to ensure that the evaluation performed in the document was done using the best science given the nature of the available information. This public health consultation was reviewed by three independent asbestos science experts. Appendix A contains further information about the peer review, the questions posed to the peer reviewers, their comments (verbatim), and ATSDR's responses to the comments.

History

El Dorado County, shown in Figure 1, was designated in 1850 with the statehood of California. The name "El Dorado" refers to a city of gold imagined to exist in the New World by Spanish conquistadors and was applied to this area of California after the 1848 discovery of gold in the Coloma area. Many towns in the present-day El Dorado County, including the county seat of Placerville, grew out of gold mining camps set up in the California Gold Rush. The areas of El Dorado County not directly related to mining were typically used as agricultural land. Today, El Dorado County extends east from the Sierra Nevada foothills to the Nevada border, and north to south from the middle fork of the American River to the south fork of the Consumnes River. Much of the population growth in El Dorado County in recent years has been on the eastern and western edges of the county as a result of expansion of the Lake Tahoe and Sacramento areas, respectively.

The unincorporated community of El Dorado Hills is located along the western boundary of the county and, at approximately 20 miles east, is considered part of the Sacramento metropolitan area. The community was a master planned community envisioned in the early 1960s to be developed over the years with a series of residential "villages," a business park, golf course, community parks, schools, and a shopping center. Initially, the population of the community grew moderately, reaching about 6,400 in 1990. In the mid-1990s, however, population growth exploded as businesses moved to the area to escape the high costs of other California locations and as Serrano developed a 3,500-acre planned community in El Dorado Hills. By 2006, the

Figure 1. Location of El Dorado County (Yellow Highlight) and Historical Places of Interest



population of El Dorado Hills was estimated at over 35,000, making it the largest community in El Dorado County.

Because of its geological history, the state of California (including portions of El Dorado County and many other counties) contains areas with a high proportion of silicate rocks high in magnesium; these rocks are called ultramafic rocks. Under certain geological conditions, ultramafic rocks can be altered to serpentinite, the greenish-colored "State Rock of California." This alteration process can also result in formation of different types of asbestos. Asbestos minerals can be formed in other types of rocks but they are more commonly formed in ultramafic rocks and near fault lines which provide necessary conditions for asbestos formation [2]. These rock types, along with geological conditions leading to formation of asbestos, have occurred not only in areas of California, but in many other places throughout the United States and the world.

For many years, geologists have been aware of the potential of serpentine rocks to contain asbestos. However, the potential for harmful exposures to the public to occur does not appear to have been realized until relatively recently. California was one of the first states to become aware of the potential for public exposure to asbestos deposits in the mid-1980s. At that time, the EPA was cleaning up a Superfund site (South Bay Asbestos) in Santa Clara County contaminated with both manufactured asbestos materials and naturally occurring asbestos from a local quarry. As part of the cleanup, EPA paved several dirt roads in the community to further reduce the chance for public exposure to asbestos [1, personal communication, Jere Johnson, EPA, November 2007]. Soon after, EPA received information that other quarries were selling asbestos-laden serpentine gravel for roads, including one in the Garden Valley area near Coloma in El Dorado County [personal communication, Arnold Den, EPA, November 2007]. EPA emergency response teams completed paving projects at Garden Valley Ranch Estates in El Dorado County and in Copper Cove Village in Calaveras County in 1986 [1-4], but it soon became clear that the number of potentially contaminated roads in California was too great to address through the Superfund emergency response process. To respond to the problem, then-California Governor Pete Wilson formed an asbestos commission which supported studies of the potential risks posed by roads. Results of testing and studies by federal and state agencies have shown the potential for asbestos exposure from serpentine gravel roads or roads cutting through natural serpentine deposits in El Dorado (Garden Valley), Calaveras (Copperopolis, Diamond XX development), Napa (Knoxville), Amador (Jackson), and Stanislaus (Oakdale) counties [5]. Approximate locations of some of the studies performed, as well as other locations mentioned in this background, are indicated in Figure 1.

Perhaps it was the information on naturally occurring asbestos from the Garden Valley publicity in combination with the sudden rapid growth in western El Dorado County in the 1990s that initiated some El Dorado Hills residents' concerns about the potential for asbestos exposure from development activities there. Residents alerted the Sacramento newspaper, the Sacramento Bee, about their concerns and in 1998 the Bee published a series of articles describing the asbestos deposits and potential for exposure [1]. The Bee also collected air samples showing the potential for elevated exposure to asbestos, particularly the amphibole varieties tremolite and actinolite which were more prevalent in the area. As a result of the media attention on this issue, the county began screening sites for naturally occurring asbestos, tightening construction standards and requiring dust control measures on construction sites. The state banned the use of gravel containing asbestos above the detection level of 0.25%, conducted an air monitoring program to assess ambient levels of asbestos in the community and in other California counties, and produced a detailed geological map of rock formations in western El Dorado County more likely to contain asbestos.

The local asbestos issue continued to be fraught with controversy, however, as homeowners concerned about property values and children's health, stone processing interests concerned about increasing regulation and liability, and county officials concerned about responding to both voter and business tax bases could not agree on the degree of risk and appropriate response. In 2002, a vein of amphibole asbestos was uncovered during construction of new soccer fields at Oak Ridge High School in El Dorado Hills. Among other consequences, this event led to:

- extensive testing of the school with involvement of federal environmental and health agencies and mitigation of asbestos in and around campus by the school district and EPA,
- a health consultation by ATSDR focused on exposures at the school, described below [6],
- additional sampling in areas away from the school by EPA to assess the potential for exposure elsewhere in the community [7], and
- characterization of area soils and rocks by the U.S. Geological Survey (USGS) to identify minerals present [8].

ATSDR was asked by a community member to evaluate past exposures at Oak Ridge High School and found, based on limited sampling results, that certain groups (coaches, student athletes, and outdoor maintenance workers) may have had exposures high enough to increase the risk of asbestos related disease [6]. ATSDR committed to evaluating exposures to the general community of El Dorado Hills, in areas away from the high school. To do this, ATSDR planned to evaluate the results of sampling conducted by EPA in 2004 in community areas of El Dorado Hills [7]. The activity-based sampling used personal monitoring techniques to measure asbestos levels a child or adult might breathe during various activities such as playing baseball or jogging down a dirt trail. ATSDR funded additional analyses of the data to gain reliable estimates of long asbestos structure concentrations, allowing a variety of risk methods to be applied. Some of the specific areas with asbestos sampling and/or detection in the El Dorado Hills area are indicated in Figure 2.

Asbestos Background

What is Asbestos? A General Term for a Group of Commercially Valuable Minerals

Asbestos refers to a special form of certain minerals that consists of long, thin, crystals (fibers) that are particularly strong, flexible, and heat resistant. They often form in bundles of very thin fibers called fibrils; their shape and flexibility means they can be woven or processed easily, but because they are silicate-based minerals, they don't react with other chemicals, conduct electricity, degrade, or burn. Asbestos minerals have been used for thousands of years. However, the scale and variety of uses, and the number of workers who mined and processed the asbestos, was small until after the industrial revolution, in the late 1800s.

Although many minerals can form into fibers with properties of asbestos, only a few varieties were plentiful enough and had the right properties to be profitably mined. The term *asbestos*

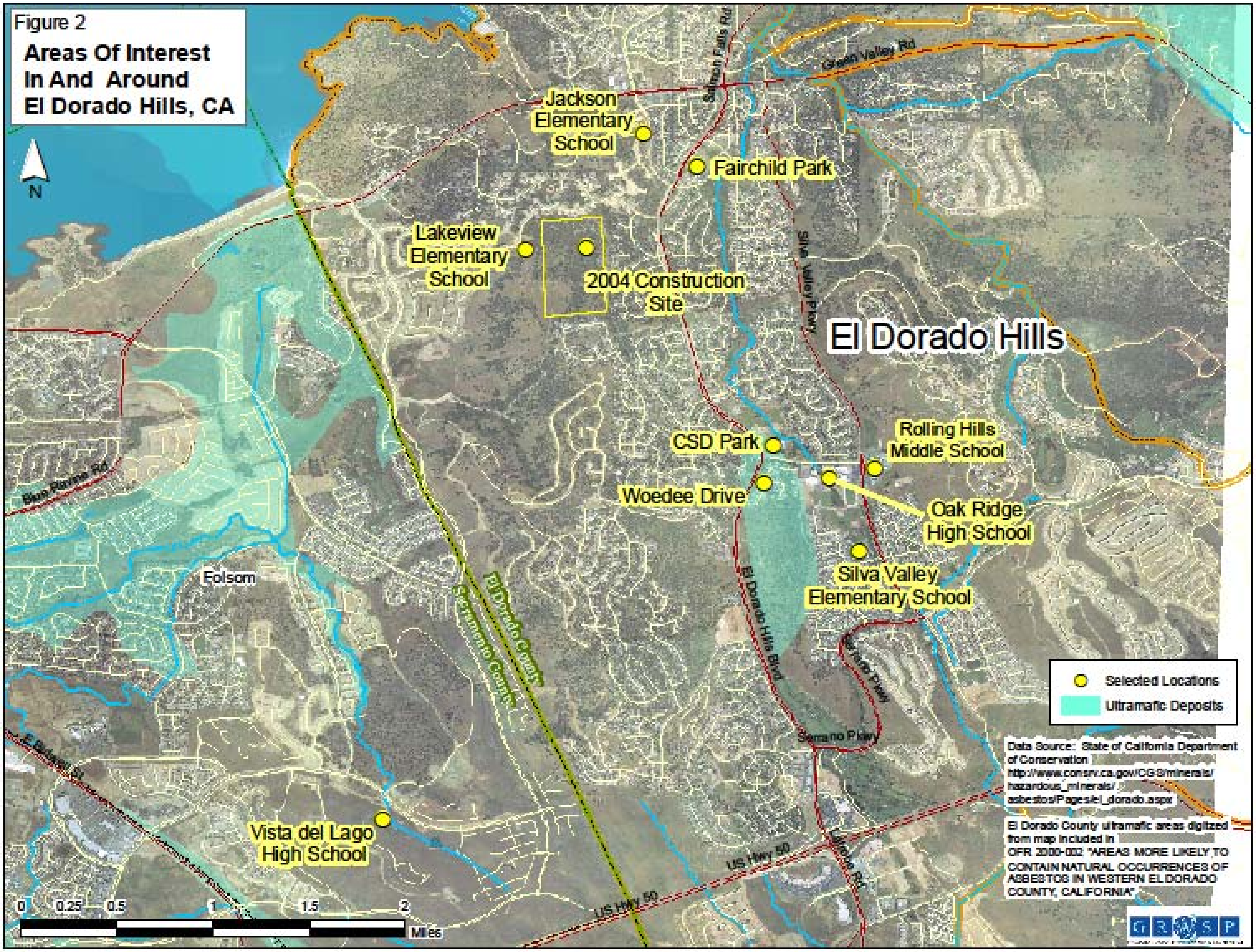
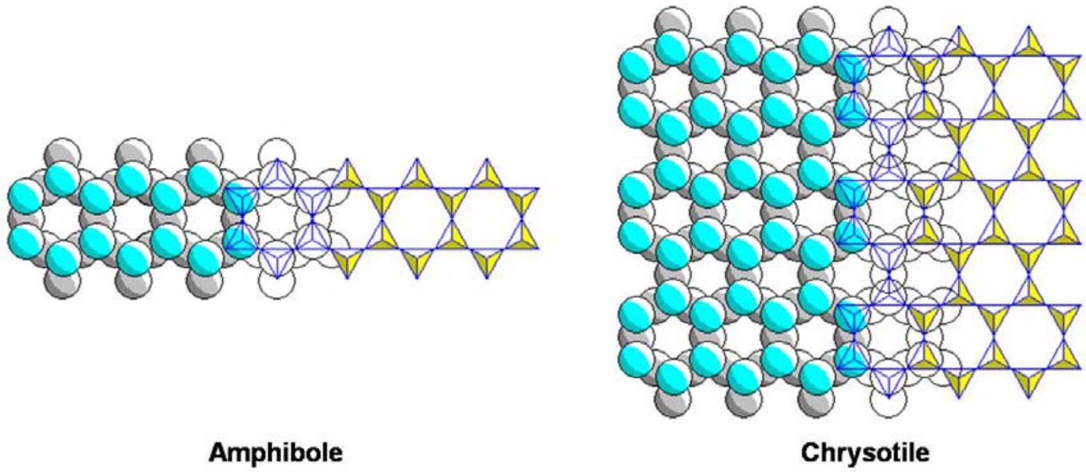


Figure 2
Areas Of Interest
In And Around
El Dorado Hills, CA
N
Jackson Elementary School
Fairchild Park
Lakeview Elementary School
2004 Construction Site
El Dorado Hills
CSD Park
Rolling Hills Middle School
Woedee Drive
Oak Ridge High School
Silva Valley Elementary School
Folsom
Vista del Lago High School
Green Valley Rd
Salmon Falls Rd
Silva Valley Pkwy
Blue Ravine Rd
El Dorado Hills Blvd
Serrano Pkwy
US Hwy 50
El Dorado County
Sacramento County
0 0.25 0.5 1 1.5 2
Miles
Selected Locations
Ultramafic Deposits
Data Source: State of California Department of Conservation
http://www.conserv.ca.gov/CGS/minerals/hazardous_minerals/asbestos/Pages/el_dorado.aspx
El Dorado County ultramafic areas digitized from map included in
OFR 2000-002 "AREAS MORE LIKELY TO CONTAIN NATURAL OCCURRENCES OF ASBESTOS IN WESTERN EL DORADO COUNTY, CALIFORNIA"

came to refer only to those commercial varieties: chrysotile, amosite, crocidolite, anthophyllite, actinolite, and tremolite. Chrysotile, or “white asbestos,” was (and is) the most prevalent form of asbestos used commercially. Amosite, an acronym for the Asbestos Mines of South Africa, where it was mined, and also known as “brown asbestos,” had properties making it especially useful in ship and other insulation applications. Crocidolite, or “blue asbestos,” was mined predominately in South Africa and Australia and used in World War II gas masks and cigarette filters, among other products. The remaining varieties (anthophyllite, actinolite, and tremolite) were mined and used in limited quantities in the past but never reached the market levels of chrysotile, amosite, and crocidolite [9]. These six types of commercial asbestos are all formed from microscopic silicate tetrahedral units and fall into two general classes as depicted in Figure 3. In *serpentine asbestos* minerals, the silicate tetrahedra form in sheets which roll to form asbestos fibers—chrysotile asbestos is the only variety of asbestos in this class. All the other commercial asbestos varieties are *amphibole asbestos* minerals, in which the silicate tetrahedra form in double chains.

Figure 3. Structural Differences Between Amphibole and Serpentine (Chrysotile) Asbestos.



Both amphibole asbestos and chrysotile have a basic framework of silica tetrahedra, where a blue silicon atom is surrounded by gray oxygen atoms; oxygen atoms are shared between tetrahedra to form polymers with different structures. In amphibole asbestos, the polymer forms as a double chain (shown on the left) which can form long, thin fibrous structures. Chrysotile, in contrast, forms a sheet structure as illustrated on the right. Because of ionic charge imbalances the sheet tends to roll up in thin tubes which create the fiber. [Diagrams used with permission from Steven Dutch, Professor, University of Wisconsin – Green Bay]

In addition to identifying the chemical composition and crystal structure, commercial producers and mineralogists identify asbestos by determining if it has the desired properties for a commercial product. The following excerpt from a 2002 USGS open-file report lists the typical features of an asbestos sample:

> These fibrous minerals…are found in bundles of fibers which can be easily separated from the host matrix or cleaved into thinner fibers; the fibers exhibit high tensile strengths, they show high length:diameter (aspect) ratios, from a minimum of 20 up to greater than 1000; they are sufficiently flexible to be spun; and macroscopically, they resemble organic fibers such as cellulose [10].

To summarize, there are composition, crystal structure, and bulk properties of the mineral sample that together determine whether a particular mineral could be considered asbestos. A mineral sample of one of the six asbestos varieties would not be considered true asbestos if its fibers did not meet the above description. Likewise, some minerals not included in the six varieties may form asbestos-like (asbestiform) fibers, but would not be considered true asbestos in the commercial sense. This is an important distinction for understanding some of the current controversies regarding regulation and risk assessment for asbestos and other related mineral fibers. These controversies have their roots in the revelation of significant adverse health effects in men and women who worked with and around asbestos materials and products. Differing usages of the term asbestos were introduced as the number of perspectives on the varying properties of these materials increased [11].

Disease and Death Caused by Breathing Around Asbestos Materials

As industrial uses of asbestos grew in the late 19th century, it became evident that asbestos workers were disproportionately afflicted with lung diseases. British, French, and Italian reports highlighted the progressive nature of the fibrotic disease and its latency (the delay between exposure and the onset of symptoms of disease—for asbestos related diseases latencies can range from 10 to 40 years) around the turn of the 20th century, and the first named case of asbestosis was described in 1906 [12]. Evidence mounted, and by the 1920s, American and Canadian insurance companies refused to insure asbestos workers due to "the injurious nature of the industry". By the mid 1900s, many studies had shown that asbestos exposure also caused elevated rates of lung cancer, pleural abnormalities, and mesothelioma among workers. By the time the U.S. Occupational Safety and Health Administration (OSHA) was established in 1972, asbestos exposure was a known workplace hazard, and its regulation was one of the first promulgated by the agency. As increasing information showed asbestos diseases in workers' household contacts, people who lived near asbestos mines and processing plants, and people around the world who lived near asbestos deposits, worker limits were reduced and many countries moved to ban the use of asbestos altogether. The regulation of asbestos exposure in the workplace and elsewhere led to another perspective on the appropriate definition of asbestos, which will be described further in the Defining "Asbestos" – Occupational Safety and Regulatory Perspectives section below. First, though, the major asbestos-related diseases and their relation to worker and community exposures will be discussed.

It is intuitive that breathing in asbestos would be associated with diseases related to the respiratory system, and diseases of the lung and pleural membrane surrounding the lungs have been extensively studied. Breathing asbestos is also associated with cancer of the larynx, and it has been suggested that breathing asbestos may increase the risk of autoimmune diseases, cancers of the gastrointestinal system, and other non-respiratory diseases [13]. Although these diseases are of concern, the focus of this discussion will be on lung and pleural diseases.

Lung and Pleural Cancers Associated with Asbestos Exposure

Lung Cancer is a disease where the epithelial cells lining the lung grow out of control. They may invade surrounding tissues or metastasize to cause cancer in other tissues in the body. For both men and women in the United States, lung cancer is the second most common form of cancer (behind prostate cancer for men and breast cancer for women). Lung cancer is the leading cause of cancer deaths [16]. Asbestos exposure has been known to cause lung cancer in asbestos workers since the early 1920s (though published studies were not available until many years later) [12]. Although asbestos exposure is a known causative agent, exposure to tobacco smoke remains the major risk factor for lung cancer. Combining asbestos exposure with tobacco smoke exposure greatly increases the risk for lung cancer over the sum of both factors. Other lung cancer risk factors include exposure to radon gas or some forms of silica or chromium and personal genetics [17].

In communities exposed to asbestos, lung cancer rates were often elevated compared to expected rates [18,19,15]. In many cases, however, smoking data from the population (which could strongly influence lung cancer rates) were not available or reported. Because of the number of different risk factors contributing to lung cancer risk, it is difficult to study the effects of community asbestos exposures on lung cancer rates.

Mesothelioma is a cancer of the mesothelium, the membrane surrounding internal organs like the lung (pleural mesothelium), digestive organs (peritoneal mesothelium), or heart (pericardial mesothelium). Asbestos exposure has been associated with mesothelioma in all these locations, but is most frequently associated with mesothelioma of the pleura and peritoneum [12,24,25]. Mesothelioma is a rare cancer, usually assumed to occur at a rate of about 1 in 100,000 in a typical industrialized country. In all but the rarest of cases, mesothelioma is associated with exposure to asbestos or another durable mineral fiber. Because the latency period from first exposure to disease presentation is so long (20-50 years) and because the disease is rapidly fatal after diagnosis (average survival is on the order of 15 months), it is difficult to obtain accurate information on potential past exposures from victims of this disease. However, some studies have described cases of mesothelioma where the only exposure to asbestos was incidental, such as working in a place where a short-term renovation disturbed asbestos-containing materials or riding a bicycle regularly in the vicinity of an asbestos plant [26,27]. Other studies have suggested that genetic factors in combination with mineral fiber exposure may increase risk of mesothelioma [28].

Mesotheliomas were reported in asbestos worker populations beginning in the middle 1900s, and it soon became evident that nonoccupationally exposed cases were present as well. Because mesothelioma may be detected in persons with lower exposures compared to asbestosis or lung cancer, and because it is almost always associated with asbestos exposure, it is often studied in environmental exposure situations. Communities exposed to asbestos or similar fibers have often been identified by elevated rates of mesothelioma, leading researchers to search for the causative agent. For example, this is how exposure of residents to asbestos from local materials was discovered in Turkey [22], New Caledonia [29], Sicily [30], Greece [31], and China [15].

Lung and Pleural Noncancerous Diseases Associated With Asbestos Exposure

Asbestosis is a noncancerous disease that has been identified in asbestos workers since the early 1900s. Asbestos fibers lodge within the lung, resulting in scar tissue formation which reduces lung elasticity and function. The disease progresses, typically slowly, and can eventually be fatal.

Asbestosis is typically thought to require very high levels of asbestos exposure over many years. However, at least one case report described a worker who developed the disease many years after a relatively brief (months) period of high-level exposure [14]. Some studies have shown increased rates of asbestosis in communities living near asbestos deposits (in Da-Yao, China, for example [15]), but these communities may have had unusually direct or high-level exposures to asbestos. In general, the lower-level exposures expected in most communities suggest that asbestosis is not a likely health outcome in most community exposure situations.

Pleural changes are abnormalities observed in the pleural mesothelium, the membrane lining the chest cavity and covering the outside of the lungs. Pleural changes are considered a marker of asbestos exposure and may or may not result in a loss in lung function. Pleural changes can include areas of pleural thickening, calcification (plaques), or pleural effusions. Pleural plaques were first described in asbestos factory workers in 1931 [12]. Pleural changes resulting from asbestos exposure are typically observed bilaterally (on both sides) on the parietal pleura (the exterior membrane closest to the chest cavity). Occasionally, pleural abnormalities may also be associated with a history of chest trauma, chest surgery, or previous infections.

Increased rates of pleural abnormalities are often seen in asbestos-exposed communities. One would expect a rate of less than 1% in an unexposed population [20]. In contrast, the rates of pleural abnormalities in asbestos-exposed communities were, for example, 18% in Libby, Montana [21]; 38% in Anatolia, Turkey [22]; and 40% in Corsica, France [23].

Defining "Asbestos" – Occupational Safety and Regulatory Perspectives

As was mentioned above, the need to regulate exposure to asbestos in the workplace and elsewhere led to yet another perspective of the definition for asbestos, one focused on characterizing the causative agent of the respiratory disease observed in workers. By 1972, due to the documented elevated rates of disease in workers, asbestos was a known workplace hazard. Because disease was associated with inhalation exposure, early industrial hygiene controls had focused on reducing the dust and fiber levels in workplace air. Initially, dust levels were monitored using the midget impinger, an apparatus which measures particles in air (in units of million particles per cubic foot, or mppcf). As it became clear that asbestos was more toxic than dust in general, optical microscopic methods were developed that could measure the elongated particles considered to originate from the processed asbestos materials and to pose the greatest risk. Phase contrast microscopy (PCM) was prescribed for monitoring occupational air fiber levels in U.S. occupational regulations [32]. This method followed an earlier British method which defined fibers as particles greater than 5 micrometers (μm) in length and with a length to width ratio (aspect ratio) of 3:1 or greater; results are presented in units of fibers per cubic centimeter (f/cc) [33]. These specifications were selected for convenience and as a result of the optical limitations of PCM. The specifications had no relationship to commercial or toxic properties of asbestos materials [personal communication, Dan Crane, OSHA, November 2007]. In addition, the PCM method, due to resolution limitations, only detects fibers with diameters greater than about 0.25 μm. Although it was recognized that PCM was unable to detect a large number of the asbestos fibers in an asbestos workplace, PCM has been and remains in use in the occupational setting as an index for monitoring and regulating harmful exposures [33]. OSHA limits uses PCM concentrations as measured using the NIOSH 7400 standard method.

The development of transmission electron microscopy (TEM) allowed much greater resolution than optical methods (diameters as small as 0.002 μm can be visualized). In addition, the techniques of selected area electron diffraction (SAED) and x-ray energy dispersive spectroscopy (EDS), often available on a TEM, could give detailed information on particle crystal structure and elemental composition, allowing specific identification of asbestos minerals. The NIOSH 7402 method is a TEM-based method which determines percentage of asbestos and nonasbestos fibers in the PCM-sized range of an OSHA compliance sample. This percentage can be used to "correct" the PCM result and obtain the actual asbestos fiber concentration in an industrial atmosphere containing asbestos and non-asbestos fibers.

TEM is often used to determine the number of asbestos structures meeting the PCM fiber size criteria and mineralogical definition; the concentration resulting is referred to as PCM equivalent (PCMe) structures per cubic centimeter (s/cc). PCMe s/cc measurements are also often used interchangeably with PCM f/cc measurements in risk methods. However, this introduces considerable uncertainty since the correlation between PCM and PCMe is not well defined [34].

In the early 1980s, the EPA Level II (Yamate) method was drafted in an attempt to standardize various laboratories' TEM methods for airborne asbestos. This draft method was not formally adopted by EPA; however, it came to be generally accepted as the method for TEM analysis of asbestos in air [35]. The method counts structures greater than 0.5 μm in length with a 3:1 or greater aspect ratio and documents asbestos fibers as well as bundles, clusters and matrices.

In 1986, the Asbestos Hazard Emergency Response Act (AHERA) was enacted as an amendment to the Toxic Substance Control Act (TSCA) to provide a regulatory framework for inspection and abatement of friable (easily crumbled) asbestos-containing materials (ACM) in schools. This legislation also laid out procedures for the removal of existing ACM and air testing protocols to ensure that removal did not contaminate the schools and that cleanup was complete [36]. Air testing analytical procedures specified by AHERA were similar to the Yamate method but simplified some aspects. The method uses TEM and counts structures greater than 0.5 μm in length with a 5:1 or greater aspect ratio; the resulting concentration will be referred to herein as total TEM structures per cubic centimeter (s/cc). Individual structure data is not documented in the AHERA method, but the concentration data is listed separately for structures less than and greater than 5 μm in length [37]. Air samples collected inside a containment area where removal took place and collected after using leaf blowers or fans to disturb any dust are statistically compared to air samples collected outside the containment area. If the indoor total structure count falls below a reference value or there is no statistical difference between indoor and outdoor air, the area is cleared and prepared for reoccupancy [35]. Because the AHERA method was codified into federal regulations, it has become more common than the Yamate method.

In 1995, the International Standards Organization (ISO) released the ISO 10312 method, which expanded classifications and reporting for asbestos structures compared to the Yamate and AHERA methods [38]. The ISO 10312 method is far more time-consuming and expensive than other methods, but captures data in a way that is more detailed and that allows re-evaluation for different dimensional characteristics if changes in regulatory requirements or medical evidence warrant [35]. The ISO 10312 method counts structures and fibers greater than 0.5 μm in length and greater than 0.002 μm in width. The procedure is used with a minimum aspect ratio of 5:1, but allows for using 3:1 when performing risk assessments (U.S. regulations specify 3:1 so this is why ISO allows flexibility; neither 5:1 or 3:1 aspect ratios are health-based). ISO 10312 results are reported in units of total TEM s/cc. There may not be an exact correspondence between ISO 10312 and AHERA total TEM s/cc counts due to structure definition differences; however, for the purposes of this document we will consider the concentrations equivalent and refer to each as total TEM s/cc.

In summary, the occupational safety and environmental regulatory agencies base their standards on various analytical methods which define fibers or structures to be counted in specific ways. Clearly, there are differences between regulatory, analytical, commercial, and mineralogical asbestos definitions—and little is known about how well these various definitions describe the actual agent responsible for causing respiratory disease (the medical or toxicological definition of asbestos). As more is learned about asbestos' mechanisms of action in causing disease, it may be possible to refine regulatory definitions to better reflect the toxic nature of asbestos and to determine the appropriate relationship between regulatory, analytical, commercial, and mineralogical definitions. It is doubtful that this knowledge will be available and accepted any time in the foreseeable future.

Naturally Occurring Asbestos (NOA)

As described above, asbestos minerals have been mined and used in products throughout the world. Despite a reduction in asbestos use, mines still operate; the largest producers include Canada, Russia, China, Kazakhstan, Brazil, and Zimbabwe [39]. While all asbestos is ultimately natural in origin, from a public health perspective, the term NOA is used to refer to asbestos and asbestos-like minerals that are not intentionally mined or used, but whose disturbance in the environment could cause exposure and, possibly, asbestos-related disease. NOA deposits have been described in many locations, including Turkey, Cyprus, China, New Caledonia, Europe, and the United States. In some cases, the presence of NOA correlated with increased rates of mesothelioma and other asbestos-related disease in the affected community [15,21-23,29-31,40]. Asbestos-related disease has also been documented in towns where exposure was to naturally occurring mineral fibers that are chemically distinct from commercial or regulated forms of asbestos—such as the amphibole fluoro-edenite or the zeolite mineral erionite [41,42].

Natural occurrences of asbestos (former mines, former prospects, and reported occurrences) have been mapped by the USGS for the Eastern, Central, Rocky Mountain, and Southwestern states [43-46]. Reported occurrences are typically in mountainous regions such as along the Appalachian Mountain chain or the Sierra Nevadas. The California Geological Survey has published maps of rock formations more likely to host NOA at both the state level and certain county levels (including El Dorado County); these are available on the Internet from http://www.consrv.ca.gov/cgs/minerals/hazardous_minerals/asbestos/Pages/Index.aspx [47,48].

Uncertainty Related to NOA Exposure and Potential for Developing Asbestos-related Disease

Because historical community NOA studies from other locations around the world documented disease, we have concern about NOA exposures in the United States. Unfortunately, most of the community NOA studies did not quantify or characterize the exposures well enough to allow comparison with measured NOA exposures in the United States. This makes determining the proper level of concern difficult. Currently, we estimate the risk of disease by applying methods based on historical worker studies (discussed in the “Asbestos Risk Assessment Methods” section below) to the exposures occurring in NOA situations. There is a great deal of uncertainty involved with this as will be discussed further in this section.

To evaluate risk ATSDR needs to have reasonably accurate exposure data, which requires collection of representative samples, analysis of the samples to reveal the quantity of NOA in the sample, and an understanding of activities in the community that could lead to exposure. ATSDR currently recommends activity-based sampling methods using ISO 10312-type analytical methods to give the best picture of asbestos in the community combined with community-specific exposure assumptions; however, even the best exposure data are still difficult to interpret with respect to disease risk. This is because there are many differences between NOA exposures in the community and typical worker asbestos exposures that may affect the degree of risk. These include differences in the people being exposed, the types, shapes and sizes of the asbestos they are exposed to, the frequency of the exposure, and the amount of time they are exposed.

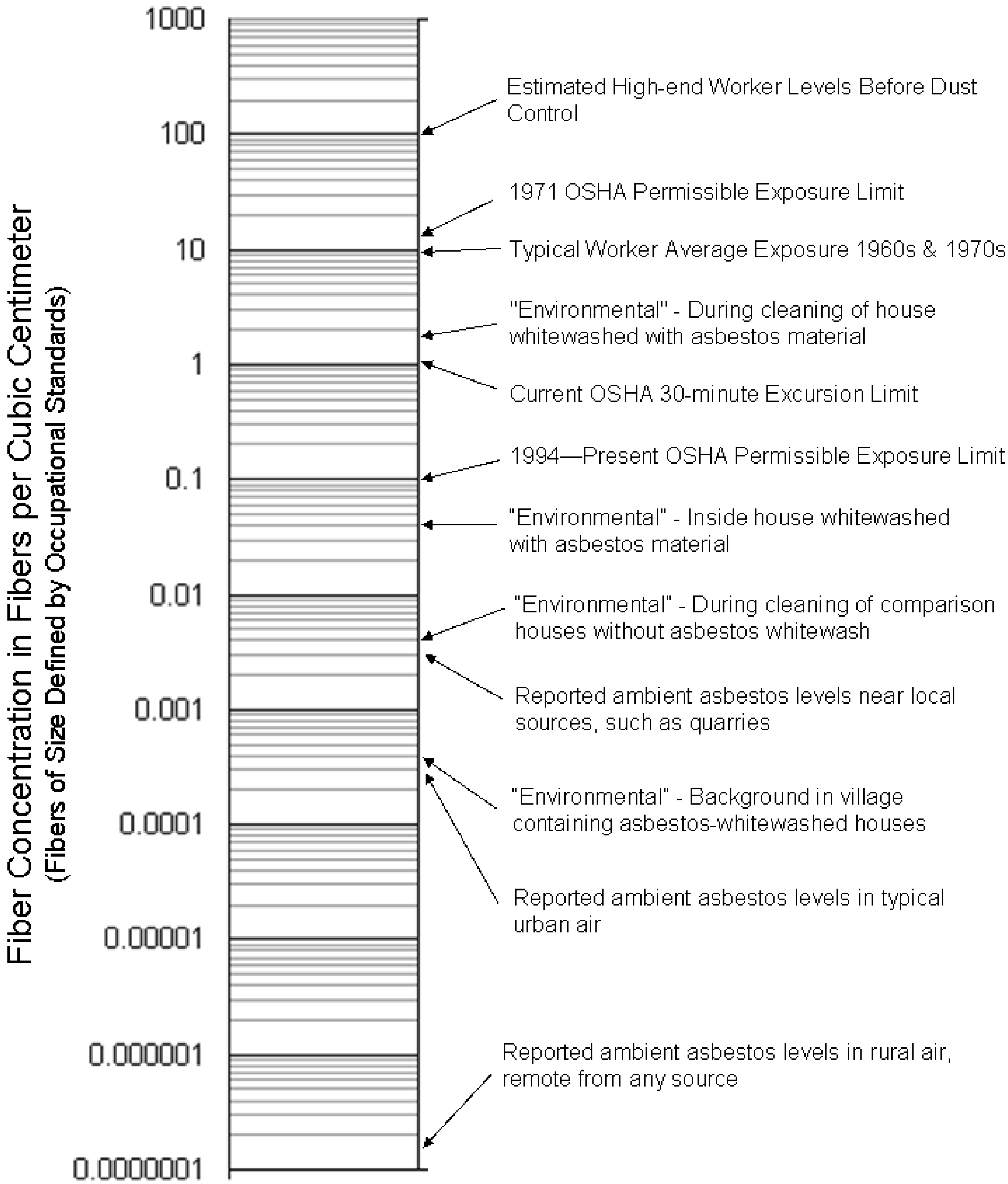
The methods used to estimate risk are based on old exposure/disease studies of asbestos workers. Typically, these workers were healthy males in the prime of life, as contrasted with communities that could include children, the elderly, or people with underlying medical conditions making them more susceptible to asbestos-related health complications. The levels of asbestos the workers breathed were typically much higher than would be expected in a community situation. As illustrated in Figure 4, early asbestos workers experienced asbestos concentrations hundreds or thousands of times higher than current occupational limits or asbestos concentrations expected in NOA areas. In addition, these workers’ exposure was more frequent, more regular, and lasted longer than we would expect in a community situation.

Finally, it seems intuitive that the type, size and shape of asbestos particles breathed in by asbestos workers were relatively consistent, because they worked with similar processes on commercial asbestos fibers every day. Although the shape and size of the asbestos fibers breathed by a worker could vary depending on the area of the plant or process he or she worked with, NOA exposures typically include a much wider range of asbestos fiber types, shapes and sizes as well as a large percentage of non-asbestos particles and/or accessory minerals. Unfortunately, comparing fiber mineralogy and size distributions between exposures of asbestos workers and people exposed to NOA is impossible at this time—the historical data on worker exposures simply does not contain such detailed information. There is some effort to analyze archived historical air sampling filters to obtain this information, but it is a task requiring significant resources and time.

Differences in worker and NOA exposure add uncertainty because we are not sure whether the risk methods developed from worker studies are directly applicable to NOA exposures. In addition, the risk methods themselves contain a great deal of uncertainty, most importantly that they all rely on obsolete sampling and analysis data from historical worker studies.

All of these factors add uncertainty to the public health concern regarding NOA exposure. Scientists are currently working to eliminate some of these sources of uncertainty, but this effort will likely take many years.

Figure 4. Comparison of Occupational and Nonoccupational Asbestos Levels



NOTE: This schematic compares generalized estimates of past occupational exposures, past and present occupational limits, "environmental" exposures where local asbestos deposits were used for whitewashing houses, and ambient asbestos levels reported for various locations in the United States.. The estimates are placed on a "log" scale, which allows widely different values to be seen on the graph—each heavy line is a value ten times the next lower heavy line. The overall exposure any person receives is a function both of the level as shown here and the length of time for which the exposure continues. Values are for comparison and context only. Assumptions and sources listed in Appendix B.

Risk

Risk is defined by Byrd and Cothern as "the probability of a future loss" [49]. This could include being struck by lightning, getting in an accident, losing money at the black jack table, or almost any human activity one can think of that can have a negative outcome. In this document we try to predict the risk of contracting lung cancer or mesothelioma from environmental exposures to asbestos. Risk can be viewed as being either a voluntary or involuntary process. Voluntary risks are those in which the individual partakes in the risk knowingly (for example, going skiing, gambling, scuba diving, or swimming in shark-infested waters). Involuntary risks are those that one may not know about or that one may have little control over, such as cosmic radiation, being hit in the head by a meteor when walking down the side walk, or being exposed unknowingly to environmental contaminants. Most people are willing to accept a higher risk when the risk is of a voluntary nature, perhaps because people feel more "in control" of voluntary risks than involuntary risks. However, people and communities can also take action to reduce the risk from involuntary sources. This document and its recommendations discuss how risk from environmental sources of asbestos can be reduced.

Risk is expressed numerically as a probability. Numerically the range of probabilities span from 0 to 1. Zero means there is absolutely no risk of a "future loss", and 1 means the risk of "future loss" is certain, 100%. For example, based on the entire population and the rates of cancer in the U.S., a person in the U.S. has a 1 in 2.5 (0.4) chance of developing some kind of cancer in his or her lifetime [50]. The same person has a 1 in 5,000 (.0002) chance of being struck by lightning. [51].

People deciding whether to participate in a risky activity or regulatory agencies determining allowable levels for contaminants try to assess the risk resulting from the activity/contaminant and set it at an "acceptable" level. Unfortunately, determining what constitutes an acceptable risk is not straightforward. The nature of the risk (voluntary vs. involuntary), the potential benefits obtained, and the person/population involved may change what is found to be "acceptable".

For environmental contaminants, EPA outlined their policy on acceptable risk from carcinogens in the environment in a 1991 memo [52]. The memo states:

> EPA uses the general 10^{-4} (1 in 10,000) to 10^{-6} (1 in 1,000,000) risk range as a "target range" within which the Agency strives to manage risks as part of a Superfund cleanup.… A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions, including any remaining uncertainties on the nature and extent of contamination and associated risks. Therefore, in certain cases EPA may consider risk estimates slightly greater than 1×10^{-4} to be protective.

To put this into context, if the additional cancer risk resulting from exposure to a contaminant is 1 in 10,000, that means that out of 10,000 people being exposed to that contaminant for a specified length of time, usually a lifetime, one additional cancer might develop from the exposure, above the normally expected number of cancers (4,000 using the general U.S. rate of cancer above).

Comparisons of Risk

Sometimes it is useful to compare risks to other well known risks to better understand the magnitude of risk. Many people in El Dorado Hills asked ATSDR to provide them with information on everyday risks people face that they could compare with risk estimates for excess cancer from asbestos exposures. They believed this would provide them with some perspective and allow them to determine if the asbestos exposure was a risk they were willing to live with. ATSDR has reservations about making such comparisons, because they could be perceived as an attempt to minimize—or exaggerate—the actual risk posed by potential asbestos exposures in the area (see Covello *et al.* [53] for more details). Over the past several years, ATSDR has worked to maintain scientific integrity and objectivity while still responding to community concerns—for this reason, we present the following comparisons with the sole intent of giving perspective—not judgment.

Table 1 presents estimated lifetime risks that may be used for comparison. The lifetime risk is the risk of the occurrence at any time in an individual's life. Lifetime risk is inherently much higher than the risk of an event occurring in any particular year of a person's life, such as may be documented in annual mortality statistics. In addition, the lifetime risk estimates in Table 1 are based on the numbers of people experiencing that event, the total population, and average life expectancy; some people will have much greater risks than others. For example, the lung cancer risk is based on the entire population—because smoking is thought to account for as many as 90% of all lung cancer deaths, the risk for smokers is much greater than for non-smokers, or the population as a whole. Similarly, a person's risk of being struck by lightning will be much smaller if he or she stays inside during thunderstorms and follows other safety recommendations.

Table 1. Lifetime Risks for Selected Events

Event/Risk	Lifetime Risk of Occurring	Lifetime Risk out of 10,000	Source
Being Killed by a Venomous Animal or Plant	0.00003	0.3	National Safety Council [54]
Being Struck by Lightning	0.0002	2	National Weather Service [51]
Estimated Additional Cancer Risk from Hazardous Air Pollutants, El Dorado County (no asbestos included)	0.0003	3	Scorecard. The Pollution Information Site [55]
Drowning	0.0009	9	National Safety Council [54]
Dying in a Motor Vehicle Accident	0.01	100	National Safety Council [54]
Being Diagnosed with Cancer of the Colon or Rectum	0.05	500	National Cancer Institute [50]
Being Diagnosed with Cancer of the Lung	0.07	700	National Cancer Institute [50]
Being Diagnosed with Cancer (all causes)	0.4	4,000	National Cancer Institute [50]
Developing Arthritis in the Knee	0.4	4,000	Murphy et al. [56]

Risk Assessment Methods

General Concept

The purpose of the risk assessment method is to predict the possibility of an adverse health effect (disease) occurring given a particular hazardous substance exposure. The way this is done is by examining studies where the relationship between exposure and the resulting adverse health effects is known and assuming the same relationship holds for a related exposure of interest. This process, for the case of asbestos, is summarized in the following steps:

- Experimental studies provide the basis for determining the relationship between exposure and resulting disease. These can include *toxicological studies*, animal- or cell-based experiments where biological effects from different asbestos exposures are measured in the laboratory environment, or *epidemiological studies*, analyses of disease and/or mortality rates in cohorts (groups) of asbestos workers. Although both toxicological and epidemiological studies are available, the epidemiology studies have been most commonly used for asbestos risk assessment because human data are generally considered the most relevant. The studies have almost all focused on lung cancer and mesothelioma as disease endpoints since cancers are typically the most sensitive disease endpoints.

- To relate exposure with disease, a mathematical description (a “model”) of disease risk as a function of exposure parameters is needed. The coefficients of this mathematical expression are known as “potency factors.” Lung cancer and mesothelioma are described with two different models. Details of these models are presented in Appendix C. Worker exposure data and resulting mortality are used with the appropriate disease risk model to determine the corresponding potency factor that gives the best fit to the epidemiological data.

Finally, the potency factors are used with the disease risk models to link exposure and risk for a new situation. This can be done to estimate risk of disease for a given exposure scenario; alternatively, it can be used to determine exposure levels that would correspond to an "acceptable" degree of risk. *For this step to be valid, the measures of exposure and the potential for disease in the new situation must correspond with those in the studies used to determine the potency factors. In other words, the measure of exposure (e.g., TEM or PCM) must be the same, and also the diseases monitored (e.g., mesothelioma) must be the same.*

Several asbestos risk methods have been developed over the years. Although all are broadly based on historical worker cohort studies, they use different procedures to obtain estimates of risk. Additionally, later methods have updated worker cohort information, added additional studies, or made assumptions allowing additional data manipulations to be performed in an attempt to improve risk assessment based on evolving understanding or hypotheses about asbestos toxicity.

ATSDR heard many opinions from local community members, local stakeholders, and other stakeholders and scientists about which method should or should not be used to estimate risk in El Dorado Hills. However, there remains a great deal of controversy surrounding the procedures and assumptions made in various risk methods, and no scientific consensus on the most appropriate method is foreseeable. Because ATSDR's goal is to make general public health recommendations, we only require a general sense of the degree of risk in the community. Therefore, as described in the "Summary – Asbestos Risk Methods" section on page 22 below, ATSDR decided to apply several different risk methods to the activity-based sampling data. This course of action is responsive to requests from community members and other stakeholders, will provide a range of predicted risks sufficient to make public health recommendations, and may allow comparison between risks predicted by different methods.

The following sections will give brief summaries of the most common risk methods. For brevity and simplicity, many of the details of method development cannot be discussed fully here; the interested reader is referred to the original citations for additional information.

EPA Airborne Asbestos Health Assessment Update, 1986

In 1986, EPA published the Airborne Asbestos Health Assessment Update, produced under contract by Nicholson [58]. This document is the basis for the current EPA integrated risk assessment system (IRIS) method, which will be described below [34]. Nicholson used worker cohort studies published between 1979 and 1984 which contained data on worker mortality resulting from exposure to asbestos. Fourteen studies had data on lung cancer and 4 had data on mesothelioma. Briefly, dust exposures reported in million particles per cubic foot (mppcf) were converted to PCMe by dividing them by a factor of 3. Then, a weighted linear regression technique was used to obtain the lung cancer or mesothelioma potency factor for each study; the geometric mean of all studies was used to determine the overall K_L (lung cancer potency factor) and K_M (mesothelioma potency factor). Nicholson evaluated uncertainties in the studies included and determined that the data did not justify differentiating between chrysotile and amphibole exposures. Nicholson also created tables showing additional risks resulting from different ages of initial exposure and durations of exposure, based on life table analyses using 1977 U.S. mortality data (this type of analysis will be discussed later). To produce these tables, risks associated with occupational exposure were converted to continuous exposure by multiplying by the ratio of hours in a week to the typical number of work hours, *i.e.* 7 days a week × 24 hours a day divided by 40 hours in a work week, which equals 4.2. Potency factors and risk are based on fiber concentrations measured by PCM, presented in units of fibers per cubic centimeter (f/cc).

EPA Integrated Risk Information System (IRIS) Method, 1988 (last revised 1993)

The studies and theory behind IRIS risk estimates are the same as in the Nicholson assessment. In IRIS, a different conversion between occupational and continuous exposure is applied: risks associated with occupational exposure were adjusted to continuous exposure by assuming a total breathing rate of 20 m^3 per day and 10 m^3 breathed by workers in a 8-hour workday, so the conversion factor is air breathed continuously (20 cubic meters × 7 days a week) divided by air breathed by workers during a work week (10 cubic meters × 5 days a week), which equals 2.8 [34]. IRIS calculates a unit inhalation risk, based on a lifetime of exposure, for the combined risk of lung cancer and mesothelioma and as a composite value for males and females. The unit risk value is based on risks calculated using U.S. general population cancer rates and mortality patterns without consideration of smoking habits. The inhalation unit risk, 0.23 $(f/cc)^{-1}$, is multiplied by average lifetime exposure, in units of PCM f/cc, to determine cancer risk.

Hodgson and Darnton Method, 2000

The Hodgson and Darnton method [59] offers a unique look at risk from asbestos exposure because it departs from the risk models used in almost all other risk assessments (these models as well as a more detailed description of the Hodgson and Darnton method can be found in Appendix C). Instead of assuming that risk is linearly dependent on exposure, this method models risk as a nonlinear function of exposure. It also includes some important studies, such as the South African crocidolite miner study, not considered in other methods. A disadvantage of this method is that it is difficult to compare results with the other studies because the estimated risk assumes exposure begins at age 30 and lasts 5 years; risk is estimated only for ages 40 – 80. Although there are limited means to correct for exposures earlier in life or longer durations of exposure, it would be difficult to obtain an accurate lifetime risk that could be compared against other available methods.

Berman and Crump Method, 2003

This method was developed by Berman and Crump under contract to the EPA in 2003 [60]. It reflects modifications of a 2001 draft method made in response to comments from subject matter experts participating in an EPA-sponsored peer consultation workshop on the draft [61]. This method was never adopted by EPA (although it serves as a basis for further risk assessment work by the agency, described below). However, it has been applied by various researchers and is put forth by some as an improved method for assessing asbestos risk. In the method, differing potencies are ascribed to amphibole and chrysotile fibers and greater potency is ascribed to longer, thinner fibers. Some of the assumptions and procedures of the method remain controversial (and the authors themselves have published papers studying alternate assumptions, as described later in the section “Recent Developments”). However, various stakeholders and community members requested us to evaluate risk using this method. Therefore, we evaluated risk with this method along with others to see if these factors could have a significant difference on the predicted risk of disease. Our inclusion of the Berman and Crump method is not intended to convey any value judgment as to its scientific validity.

The Berman and Crump method uses the same lung cancer and mesothelioma risk model equations as in the EPA 1986 method. Changes include the use of additional and updated epidemiology studies and more recent (2000) U.S. mortality data. In addition, an evaluation of animal inhalation studies was used to determine that fiber length provided the best correlation with toxicity. In order to convert exposure concentrations reported in human epidemiology studies to more toxicologically relevant fiber sizes, the authors of the method applied TEM-determined size distributions of materials from similar industries to the reported exposures (due to data limitations, the longest category for fiber length was greater than 10 μm). Two of the studies for which no fiber size data were available were dropped from consideration. In addition to fiber length considerations, amphibole and chrysotile were considered separately. For mixed exposures, the percentage of a study's exposure concentration for each class of asbestos was estimated using plant history, air data, or professional judgment. This allowed separate K_Ls and K_Ms for amphibole and chrysotile to be determined.

The analysis was performed on all the epidemiology studies together. The authors reanalyzed animal studies and available epidemiological data to conclude that all risk is posed by fibers greater than 10 μm long and less than 0.4 μm wide. Numerical analysis was used to find the best fit relative potency factors to minimize "spread" in the studies.

The Berman and Crump method uses a conversion factor of approximately 3 to convert occupational to continuous exposures (by assuming a total breathing rate of 20 m^3 per day and 10 m^3 per 8-hour workday, and 240 days of work per 365-day year, *i.e.*, 20 cubic meters a day × 365 days a year divided by 10 cubic meters × 240 work days a year, which equals 3.0). The conversion is incorporated into the potency factors so calculations can be performed directly [60].

California-EPA OEHHA Method, 2003

The state of California has its own method for assessing risk posed by asbestos exposure [62]. The exposure index is specified as total TEM structures, including all asbestos structures greater than 0.5 μm long with aspect ratios of 3:1 or greater [63]. However, because the unit risk was determined from epidemiology studies reporting PCM concentration results, the TEM structure count must be converted to PCM equivalents by dividing by a Cal-EPA determined factor of 320. The unit risk of 1.9×10^{-4} in units of (100 PCM fibers per $m^3)^{-1}$ gives mesothelioma risk in female nonsmokers [personal communication, Melanie Marty, Cal-EPA OEHHA, November 9, 2007]. This is the group that would have the highest mesothelioma risk. Another difference in the Cal-EPA unit risk is it was determined using an approach that considered the 95% upper confidence limit in evaluating the epidemiological studies, as opposed to the EPA and Berman and Crump methods which used a central tendency approach.

In some recent cases, the U.S. EPA has applied the Cal-EPA unit inhalation risk directly to the PCM-sized fraction determined from TEM measurements, avoiding the use of the 320 conversion factor. The conversion factor is known to be very uncertain, as it represents the geometric mean of several studies where the factor ranged from 10—1,000. However, most California air districts and the ARB use the risk guidance as written, and studies of the correlation between actual PCM measurements and PCM-sized fractions of TEM measurements would have to be performed to validate this alternate application [personal communication, John Budroe, Cal-EPA OEHHA, January 20, 2009].

Proposed EPA OSWER Interim Risk Approach, 2008

Although there were issues with the Berman and Crump method that prevented its adoption, many in the public and scientific communities criticized EPA for continuing to use the IRIS method instead of a method that assigns greater potency to amphiboles or longer fibers. In response, in the mid 2000s EPA's Office of Solid Waste and Emergency Response renewed efforts to address some of the remaining uncertainties associated with the Berman and Crump method and develop an interim asbestos risk assessment method for use until the ongoing IRIS update is complete [64].

The first part of this effort, mainly performed under contract with Syracuse Research Corporation and led by Brattin, generated a document entitled "Proposed Approach for Estimation of Bin-Specific Cancer Potency Factors for Inhalation Exposure to Asbestos" [64]. The approach expanded the work of the Berman and Crump method by including a wider range of fiber size "bins" (length, width, and mineralogy classifications) to evaluate the best fit to the worker cohort studies. The document did not include calculation of bin-specific cancer potency factors, but merely described the approach proposed to attain them.

A meeting was held of the Asbestos Committee of EPA's Science Advisory Board to discuss the proposed approach. The meeting was held in Washington, DC on July 21 and 22, 2008 and was open to the public [65]. The final report from the committee was released in November 2008 [66]. Although the committee generally supported the need for developing risk assessment methods to account for potential differences in risk on the basis of mineral types and size characteristics of asbestos, the scientific basis laid out in the proposed document was felt to be inadequate. Of particular concern was the lack of available size distribution for estimating exposure levels in the epidemiological studies evaluated [66]. Public comments made at the meeting and available for viewing on the science advisory board webpage showed a range of viewpoints, from those who supported the approach as more accurately describing greater toxicity of amphiboles and longer fibers and those who felt the approach would lead to a weakening of asbestos regulations [64].

Recent Developments

In August 2008, Berman and Crump published updates of potency factors for lung cancer and mesothelioma using cohort data updates published since the EPA 1986 method [67]. Potency factors for lung cancer and mesothelioma were calculated for each identified study using more recent data. The authors discuss applicability of dose-response models for lung cancer and mesothelioma in light of more recent data, and they compare potencies between studies. Historical discrepancies in calculated potencies for studies of similar exposures (which have been a continuing question) were still present after including more recent data.

Berman and Crump suggest that study discrepancies may be addressed by accounting for fiber diameter, length, and mineral type, and they explore this topic in a companion article [68]. In this analysis, surrogate size data and mineral type information were applied to study data to see if discrepancies in calculated potency factors between studies could be improved. Statistical tests suggested that chrysotile was much less potent in causing mesothelioma (best estimates for mesothelioma potency of chrysotile were 0—1/200th that of amphibole). For some size ranges, statistical tests suggested differences in lung cancer potency between chrysotile and amphibole as well. For diameter, the authors found that the occupational study results are in best agreement when fiber exposure data includes either “all widths” or widths less than 0.4 μm rather than only widths greater than 0.2 μm [ATSDR note: this suggests that very thin fibers not normally detected by PCM have significant potency]. For length, the authors concluded that lengths between 5 and 10 μm were not necessarily non-potent, but had significantly less potency than fibers with lengths greater than 10 μm. The authors stated that no consistent evidence was found indicating potency of fibers less than 5 μm in length in causing either lung cancer or mesothelioma. No matter what assumptions were made, the authors were not successful in resolving the discrepancies in potencies calculated for different studies. The authors suggest that the available data are not detailed enough to explain the differences.

Because the focus of both of these recent articles was on trying to resolve the differences between estimated potency factors in different occupational studies, no attempt to recommend general potency factors for use in risk assessment was made. Therefore, neither of these studies can be used alone or combined with previous methods to estimate risk.

“Life Table Analysis” - Time Considerations

Age of first exposure and duration of exposure are important considerations in asbestos risk assessment. For example, early-life asbestos exposures generally carry more overall risk because, with a longer life expectancy, the individual has a longer time to develop diseases with a long latency period, and therefore more chance of developing asbestos-related disease before dying of another cause. Many of the risk methods described above develop unit risks based on average lifetime exposure to a continuous level of asbestos. This is useful for risk management purposes, but may not be fully informative for exposures that are discontinuous, have changing levels with time, or occur for periods much shorter than a lifetime. “Life table analysis” is a method for determining risk at various points in a person’s life given specific exposure patterns and using general population mortality data. It can be used with most of the basic risk methods and potency factors described above. The “life table analysis” procedure used in this health consultation is consistent with the approach used by Nicholson (EPA 1986 method) and Berman and Crump [58,60]. A full description of the procedures followed is presented in Appendix D.

Because of the way life table analysis is done, and because of the long latency periods needed for asbestos-related disease (especially mesothelioma) to develop, groups who live longer end up having a higher risk of disease. For example, women have a higher life expectancy than men, and therefore their overall risk of developing mesothelioma is higher than men’s. Smokers are a special case. Whether they are exposed to asbestos or not, a person who smokes tobacco has a higher risk of dying of lung cancer or other causes than a nonsmoker. If the person is also exposed to asbestos, their risk of developing lung cancer is increased greatly. This increased lung cancer risk has the effect of decreasing the risk of mesothelioma—because the person is more likely to die of another cause (lung cancer) before they would have time to develop mesothelioma. Similarly, a nonsmoker actually has a higher risk for mesothelioma because they are more likely to live long enough to develop the disease.

Because of these differences, many asbestos risk assessors calculate separate risks for men and women and smokers and nonsmokers. Separating risks in this way is not straightforward, because published mortality data do not document smoking status. The procedure involves using data on relative risk of dying of smokers vs. nonsmokers (data was collected in the 1980s) along with more recent data on prevalence of smoking in men vs. women to construct mortality tables for the separate groups of male smokers and nonsmokers and female smokers and nonsmokers [67,70,60]. Other groups have chosen to calculate risks based on only one sensitive group—*e.g.*, female nonsmokers [62].

ATSDR has chosen not to compute separate risk estimates for smokers and nonsmokers in this health consultation. This will allow straightforward use of updated mortality data without needing the (potentially outdated) relative risk data, and it does not require specific knowledge of smoking rates in this community. Further, although risks are calculated for men and women separately, we present only the range of risk for the population as a whole. We feel this is adequate and appropriate for our stated goal of obtaining a general idea of potential risk in the community.

Summary – Asbestos Risk Methods

Each risk method uses a specific fiber/structure definition of exposure to correlate with mortality data and describe risk. This exposure index is a measure of a subset of mineral structures in a given exposure that could be used effectively in the method to describe risk associated with that exposure. However, it is likely that elongated mineral structures not meeting a particular index definition also contribute risk. Further research in mineral structure size populations for different types of exposure as well as dimensional and mineralogical effects on asbestos toxicity for various disease endpoints may eventually allow refinement of exposure indices to correspond more closely with known toxic properties. Today, however, evidence is conflicting and arguments for any particular index are debated too strongly for a reasonable public health practitioner to select one alone.

In light of the fact that no one risk method has been accepted fully (and exclusively) in the scientific or regulatory communities, ATSDR was faced with the question of how to determine the risk posed by El Dorado Hills-area exposures. The agency decided that a practical way to address this problem would be to compare risk predictions from several different methods (using the same exposure data) to get an idea of the range of predicted risk. ATSDR chose to evaluate risk using as many of the risk methods described above as possible. The Hodgson and Darnton method was not used because a lifetime risk could not be calculated accurately given the method procedures, and the 2008 OSWER approach could not be used as it did not include potency factors required to calculate risk. Therefore, ATSDR estimated risk using the IRIS method, the Cal-EPA method, the EPA 1986 method, and the Berman and Crump method. Life table analysis with the EPA 1986 and Berman and Crump methods was performed using mortality statistics from 2003, the most recent year available when we performed the analysis in 2008.

ATSDR recognizes that some of these methods are not accepted by EPA for regulatory purposes and may have scientific inadequacies. However, in this case we feel the use of alternate risk methods is justified because our objective is to make qualitative, practical recommendations to the community on the level of concern associated with exposure and ways to reduce potentially harmful exposures. We do not endorse using numerical results from our evaluation to take regulatory or enforcement actions. We caution that the risk estimates presented later in this report should be considered with these purposes in mind.

El Dorado Hills Activity-Based Sampling and Analysis

At the request of a community member, EPA collected activity-based samples in community areas of El Dorado Hills in Fall 2004. This type of air sampling uses personal monitoring techniques to measure asbestos levels a child or adult might breathe during various activities such as playing baseball or jogging down a dirt trail. Activity-based sampling is currently thought to represent the most realistic and accurate way to measure potential breathing-zone exposures. Over 300 activity-based sample filters were analyzed by LabCor (Seattle, WA) in 2004-05 using a modified ISO 10312 method, which gives detailed structure information including dimensions and mineralogy. Preliminary findings from the EPA sampling were presented to the El Dorado Hills community in May 2005, and the final report was issued in January 2006 [7]. The findings indicated that activities resulted in significantly greater asbestos exposures than measured at activity-free reference stations. More details can be found in the EPA report [7].

ATSDR planned to use these results to evaluate risk associated with the exposures; however, the initial analysis of the samples did not allow meaningful application of risk methods utilizing a "long fiber" (greater than 10 μm) exposure index. Specifically, the original analytical procedure required each filter to be counted until a minimum of 50 structures equal to or longer than 5 μm in length had been identified. In many cases, this "stopping rule" was met before any structure longer than 10 μm was counted, so that the true "long" structure concentration was not known. ATSDR funded additional analysis of the filters, which had been archived by the laboratory, to count only structures greater than 10 μm long and less than or equal to 1.5 μm wide. Because there were very few of these structures, we specified that the laboratory was to count until 10 of these structures were identified or until a total of 400 grids had been counted, whichever came first. This was anticipated to give sufficient sensitivity to allow meaningful application of "long" structure risk methods such as the Berman and Crump Method.

To conserve limited funds, ATSDR selected about 180 of the more than 300 filters for additional analysis. Samples were selected to allow description of each exposure scenario of interest and to fully describe the reference station samples. In addition, ATSDR instructed the laboratory to perform the counting at a lower magnification (which saves analysis time). Most of the structures were not so thin as to limit visibility at the lower magnification, so this was not expected to have an impact on overall structure count.

ATSDR funded the additional analysis through a contract with Eastern Research Group (ERG, Cambridge, MA), which coordinated the analysis by LabCor, the same laboratory used by EPA for the initial analysis. To facilitate turnaround time, analyses were performed concurrently, on equivalent TEM equipment, in LabCor's Seattle and Portland (OR) locations. The additional analyses were performed primarily in March-July 2007, and final data reports were delivered to ATSDR in August and September 2007. A report giving further details of the objectives and describing the findings of the ATSDR additional analysis is included as Appendix E to this health consultation.

Exposure Assumptions

The activity-based sampling results give asbestos structure concentrations for various activities that might take place in the community—the activities focused on outdoor activities like sports and exercise which might be expected to disturb NOA and result in exposure. In order to estimate a community member's typical exposure, ATSDR worked with stakeholders to develop assumptions for the length of time a person would spend doing each activity— "time-duration assumptions". Three scenarios were considered:

- The low activity case corresponds to a person who, throughout life, participates in very few outdoor activities. The only exposures beyond background assumed for this case are through required outdoor activities during school years.
- The moderate activity case corresponds to a moderate level of participation in outdoor activities, team sports, and outdoor exercise throughout life.
- The high activity case corresponds to those who spend lots of time outdoors, participate in many team sports, and continue high level of outdoor sports and exercise activities throughout life.

ATSDR developed draft exposure assumptions for each of these cases and provided them to a local citizens group and local, state, and federal stakeholders for comment. Appendix F includes the original spreadsheet containing draft exposure assumptions, comments made by the various groups, ATSDR responses indicating revisions made to the assumptions, if applicable, and the resulting revised exposure assumption spreadsheet. The revised time-duration assumptions are summarized in the next section and presented in Table 2 following that summary.

In addition to time-duration assumptions, ATSDR proposed a method of selecting and combining the air sampling results to correspond with various activities. For example, physical education activities at school were assumed to be represented by a 50/50 contribution of results for child participants in "grassy fields" scenarios (soccer, baseball) and results for child participants in "asphalt courts" scenarios (basketball, 4-square court). These "structure level assumptions" were also provided to stakeholders, and comments, changes, and responses are included with the time-duration assumptions in Appendix F. The revised structure level assumptions are summarized beginning on page 27 and presented in Table 3 following that summary.

It is important to note that the assumptions made cannot perfectly describe any individual's exposure to asbestos-related materials in the El Dorado Hills area. The goal of this exercise is to obtain a range of potential exposures which can inform the public whether the community, as a whole, is at risk for elevated exposure and disease. However, both individual differences in activities (type, location, duration, intensity) and time or spatial variations in community areas (weather patterns, maintenance activities, level of asbestos-related materials) could all cause any one person's exposure to diverge, possibly significantly, from the estimates made herein.

Notes on Revised Time-Duration Assumptions

The total time of potential exposure is assumed to be 50 weeks per year, assuming a 2-week vacation to a location without potential for asbestos exposure. Of this, 13 weeks are assumed to constitute a "rainy" period when outdoor activities are curtailed and background exposures are lower. (Online data as well as local data collected by state and private entities form the basis for this assumption [71–73].) Assuming a 45-week school year running from mid-August until early June, ATSDR therefore determined that the non-rainy school year (for estimating exposures during physical education, etc.) would be 32 weeks. A “digging” scenario describes young children participating in garden activities at school and older children participating in soil experiments through science classes. In addition to required school activities, children in the moderate and high activity scenarios are assumed to participate in extracurricular outdoor activities, split evenly between “grassy fields,” “asphalt courts,” and the New York Creek Trail, during a total of 36 weeks per year (some activities take place during the summer break).

For the 12-18 year-olds’ high activity scenario, 10 hours per week was assumed for extracurricular activities (8 hours for practice and games during the school week and 2 hours on the weekend). For the moderate scenario, 5 hours per week was assumed (half of the “high” activity level and similar to recommendations made by the U.S. Surgeon General’s Office that children older than 8 and adolescents engage in “at least 60 minutes of moderate intensity, continuous activity on most days, preferably daily.” [74]) Total hours for extracurricular activities for 5-11 year olds was the same as for 12-18 year olds, but the proportion of time spent on grassy fields or asphalt courts was increased and time on New York Creek Trail reduced, since younger children are assumed to be more likely to engage in supervised sports activities than independent exercise. Time-duration assumptions are presented in Table 2, and more details can be found in Appendix F.

Table 2. Time Duration Assumptions Used for Activities in El Dorado Hills, California

		Case: Low Activity				Case: Moderate Activity				Case: High Activity			
	Activity*	Hours per Week	Weeks per Year	fraction†	**=Hours per Year**	Hours per Week	Weeks per Year	fraction†	**=Hours per Year**	Hours per Week	Weeks per Year	fraction†	**=Hours per Year**
Age: 0-4 yrs	Child - Dry Background		37		**6216.0**		37		**5994.0**		37		**5772.0**
	Child - Wet Background		13		**2184.0**		13		**2184.0**		13		**2184.0**
	Child - Tot Lot					3	37		**111.0**	6	37		**222.0**
	Child - Bicycling (alone or on parent's bike)					3	37		**111.0**	6	37		**222.0**
Age: 5-11 yrs	Child - Dry Background		37		**5984.0**		37		**5740.0**		37		**5544.0**
	Child - Wet Background		13		**2184.0**		13		**2184.0**		13		**2184.0**
	Child - Walking on NY Trail to & from school					2	32		**64.0**	2.5	32		**80.0**
	Child - Recess	2.5	32		**80.0**	2.5	32		**80.0**	2.5	32		**80.0**
	Child - "Digging"	1	32		**32.0**	1	32		**32.0**	1	32		**32.0**
	Child - Physical Education	3.75	32		**120.0**	3.75	32		**120.0**	3.75	32		**120.0**
	Child - Asphalt Courts Play					6	12		**72.0**	12	12		**144.0**
	Child - Grassy Fields Play					6	12		**72.0**	12	12		**144.0**
	Child - New York Trail Biking/jogging					3	12		**36.0**	6	12		**72.0**
Age: 12-18 yrs	Child - Dry Background		37		**6146.6**		37		**5902.6**		37		**5706.6**
	Child - Wet Background		13		**2184.0**		13		**2184.0**		13		**2184.0**
	Child - Walking on NY Trail to & from school					2	32		**64.0**	2.5	32		**80.0**
	Child - "Digging"	0.5	3	0.57	**0.9**	0.5	3	0.57	**0.9**	0.5	3	0.57	**0.9**
	Child - Physical Education	3.75	32	0.57	**68.6**	3.75	32	0.57	**68.6**	3.75	32	0.57	**68.6**
	Child - Asphalt Courts Play					5	12		**60.0**	10	12		**120.0**
	Child - Grassy Fields Play					5	12		**60.0**	10	12		**120.0**
	Child - New York Trail Biking/jogging					5	12		**60.0**	10	12		**120.0**
Age: 19-30 yrs	Adult - Dry Background		37		**6216.0**		37		**6120.0**		37		**6024.0**
	Adult - Wet Background		13		**2184.0**		13		**2184.0**		13		**2184.0**
	Adult - Asphalt Courts Play					2	6		**12.0**	4	6		**24.0**
	Adult - Grassy Fields Play					2	6		**12.0**	4	6		**24.0**
	Adult - New York Trail Biking/jogging					3	24		**72.0**	6	24		**144.0**
Age: 31-120 yrs‡	Adult - Dry Background		37		**6216.0**		37		**6150.0**		37		**6048.0**
	Adult - Wet Background		13		**2184.0**		13		**2184.0**		13		**2184.0**
	Adult - Asphalt Courts Play					1	6		**6.0**	2	6		**12.0**
	Adult - Grassy Fields Play					1	6		**6.0**	2	6		**12.0**
	Adult - New York Trail Biking/jogging					2.25	24		**54.0**	6	24		**144.0**

* Time for activities subtracted from time for dry background.

† Used to correct for 4 out of 7 years that PE and soil experiments are required.

‡ Adult exposures are assumed to continue throughout life to a maximum of 120 years; however, the exposure only applies to the population remaining alive, so the contribution to risk in high-age years is very small.

Notes on Structure Level Assumptions

Each activity is assumed to be described by a combination of activity-based sampling results. Table 3 shows the activity-based samples included in the calculation for each activity's structure level. Each sample's result will depend on how the structure of interest is defined: for example, in the same sample, the numerical concentration of PCMe-sized fibers is different from that of total TEM structures. Later in this document, ATSDR will evaluate risk using different methods, many of which use different definitions for structures of interest.

Of note in the structure level assumptions, the grassy fields scenario is assumed to be described by the scenarios taking place on baseball and soccer fields (including grassy field composite samples). The asphalt court scenario, similarly, includes results from basketball and the Jackson playground (4-square) scenarios. Most activities used personal air monitoring results (participants in the activity-based sampling) to describe exposures. However, some scenarios (walking to school on New York Trail or recess activities, for example) were considered to be less intense than the corresponding activity-based sampling (biking/jogging on New York Trail or sport activities, respectively). In these scenarios, stationary monitoring results (corresponding to observers in activity-based sampling) were used to describe exposure.

As shown in Table 3, structure levels are determined for each scenario by combining identified activity-based sampling results. For several of the exposure measurement definitions calculated (for example, structures longer than 10 μm and thinner than 0.4 μm), the structures of interest were detected very rarely, even with the additional analysis in which up to 400 grids per sample were counted. For these cases, a "nondetect" value was assumed to truly represent the absence of that size structure in the sample, and a value of zero was assigned. The average value of all the samples contributing to the scenario is expected to adequately represent exposures to the majority of individuals in that scenario and is used herein to calculate a "mid-range" estimate of the annual exposure level. However, as an indication of "spread" in the data and to obtain a conservative estimate of the possible exposure, a "high-end" value for each scenario was also selected: the highest value detected in any of the activity-based samples contributing to that scenario. With the use of high-end values for each exposure scenario considered, the estimated yearly structure level represents a more conservative estimate of the average annual exposure The high end estimate does not represent an upper bound because the maximum detection in each scenario is averaged with the other scenarios and weighted according to the estimated time spent in each scenario over the year).

Appendix G tabulates intermediate and final results of calculations performed in this consultation. Table G1 shows yearly structure concentrations calculated using the mid-range and high-end values for each scenario, for each structure definition of interest. These concentrations are inserted into life table analysis for each risk method evaluated.

Table 3. Assumptions Used for Calculating Structure Levels for Activities	
Activity	**Values to Include in Concentration Average**
Child - Dry Background	All reference stations
Child - Wet Background	All reference stations (divided by factor of 10)
Child - Tot Lot	Personal monitors at tot lot, also observer (hi-vol)* samples at playground
Child - Bicycling (alone or on parent's bike)	Child participant personal monitors for biking scenario
Child - Walking on NY Trail to & from school	Observer (hi-vol) samples for biking and jogging scenarios on New York Trail
Child - Recess	All grassy field and asphalt court observer (hi-vol) samples
Child - "Digging"	Jackson Elementary Gardening (note only one observer (hi-vol) sample available)
Child - Physical Education	Child participant personal monitors for grassy fields, asphalt courts (including composites)
Child - Asphalt Courts Play	Child participant personal monitors for asphalt courts
Child - Grassy Fields Play	Child participant personal monitors for grassy fields (including composites from grassy fields)
Child - New York Trail Biking/jogging	Child participant personal monitors for biking scenario
Adult - Dry Background	All reference stations
Adult - Wet Background	All reference stations (divided by factor of 10)
Adult - Asphalt Courts Play	Child & nonactive adult participant personal monitors for asphalt court scenarios (no adult participants)
Adult - Grassy Fields Play	Adult participants & nonactive participant personal monitors for grassy fields
Adult - New York Trail Biking/jogging	Adult participant personal monitors for jogging scenario

* Observer (hi-vol) samples refer to stationary monitors set up nearby activities to represent observers of the activity.

Risk Estimation

Estimated lifetime risk of combined excess lung cancer and mesothelioma was calculated using several different risk methods as described previously. The methods used were:

- EPA 1986 life table analysis, using a PCM equivalent (PCMe) structure definition of combined amphibole and chrysotile structures with length greater than 5 µm, width greater than or equal to 0.25 µm and less than or equal to 3 µm, and aspect ratio greater than or equal to 3:1 [58]. These dimensions are consistent with PCM fibers as specified in the EPA 1986 method; however, it should be noted that there may be differences between PCMe (measured with a transmission electron microscope) and PCM (measured a with phase contrast optical microscope) counts. The exposure durations were as described above in Table 1, and estimation of total lifetime risk was performed by summing risks each year for all surviving population members using 2003 NCHS mortality data [75,76]. (As noted in Table 1, only the population remaining alive contributes to each year's risk, so the risk contributed by later ages is small. However, all ages with survivors [up to age 120 for the 2003 data] must be considered to estimate true lifetime risk.)

- IRIS procedure, using the same PCMe structure definition as above. Yearly exposure estimates used for life table analysis were averaged to obtain an average lifetime estimate of exposure for this method. The average lifetime exposure was then multiplied by the IRIS inhalation unit risk, 0.23 $(f/cc)^{-1}$ [34].
- Berman and Crump method life table analysis, using a structure definition separating amphibole and chrysotile structures greater than 10 μm long and less than 0.4 μm wide [60]. Life table analysis was performed as for the EPA 1986 method above.
- Cal-EPA procedure, using a structure definition of combined amphibole and chrysotile structures of length greater than or equal to 0.5 μm and aspect ratio greater than or equal to 3:1 [62,63]. As part of the procedure, total number of structures was converted to PCM equivalent structures by dividing by 320, a conversion factor determined by Cal-EPA. Yearly exposure estimates used for life table analysis were averaged to obtain an average lifetime exposure for this method. It should be noted that risk calculated using this method is only for mesothelioma risk in female nonsmokers (considered the most sensitive group) and does not include excess lung cancer risk. In addition to the official Cal-EPA method, we also examined the impact of using the Cal-EPA unit inhalation risk directly with PCMe data (bypassing the conversion step) as has been proposed by U.S. EPA.

Limitations

Each risk method relies on exposure data from historical epidemiological studies which have a great degree of uncertainty associated with them, especially in characterizing worker exposures. We do not know with certainty whether the size of particles selected in each method to describe exposures (e.g., PCM, TEM) fully or accurately captures those particles contributing to risk of disease. For each risk method, there is uncertainty in the numbers chosen as coefficients in the exposure-disease model used. For the methods that separated risk based on fiber mineralogy, there is uncertainty in the adequacy of the data to describe exposures by mineralogy. Additional uncertainty comes from the exposure assumptions we developed to use in the various risk methods. EPA’s sampling data was collected during a short timeframe at a few locations and may not fully reflect the temporal and spatial average exposures occurring in the community. Also, the activity simulations performed may not adequately represent the type, number, and frequency of activities performed throughout a lifetime or the variability of those activities between individuals.

Our goal was to get a general idea of the potential increased risk of developing disease from community exposures, not to predict a specific numerical risk. Therefore, although we recognize the inherent uncertainties, we used the available risk methods and data to obtain estimates of risk.

These estimates are presented as the lowest and highest risks predicted by each method using the exposure scenarios and concentration estimates described in the “Exposure Assumptions” section above. The ranges presented do not include any estimate of confidence around the individual predicted risks. We did not analyze the sensitivity of the results on uncertainty in any one variable. We are only showing the range of estimated increased risk calculated based on the four methods evaluated and specified exposure assumptions.

Risk Results

Estimated risk of lung cancer and mesothelioma combined was calculated for each method (except the Cal-EPA method which only calculated mesothelioma risk), using asbestos structure levels for low, medium, and high activity patterns, for men and women, and for mid-range and high-end values used in calculating exposure scenario levels. This allowed a range of potential lifetime risk to be generated. To get an indication of the relative contribution of activities and background exposures, the calculations were repeated with background levels for all ages set to zero. Results are summarized in Table 4 below.

Table 4. Ranges of Risk Predicted by Various Methods

Risk Method	Structure Definition	Range of Estimated Risk out of 10,000*		Analysis Procedure
		Lifetime Estimated Risk	Risk Contributed by Activities†	
EPA 1986	PCMe Structures, combined amphibole / chrysotile	3 to 22	0.1 to 8	life table analysis
IRIS	PCMe Structures, combined amphibole / chrysotile	1 to 10	0.02 to 3	averaged over lifetime
Cal-EPA	Total Structures, ≥0.5 μm long and ≥3:1 aspect ratio, combined amphibole / chrysotile	0.1 to 0.6	0.004 to 0.3	averaged over lifetime (meso only)
Berman and Crump	Structures >10 μm long and ≤0.4 μm wide, separate amphibole / chrysotile	0.3 to 3	0.03 to 3	life table analysis

* Note that ranges do not indicate confidence intervals, merely the range of risks predicted for each model for various activity level, gender, and exposure concentration assumptions. See "Limitations" section in text.

† Lifetime risk with background concentrations set to zero.

Discussion of Risk Results

The range of estimated risk for each risk method represents the variation in risk for different exposure scenarios (low to high activity throughout life), gender, and the use of mid-range to high-end exposure concentration estimates for each activity. It is important to note that the high end of this risk range is not an overly conservative estimate. Even when high-end exposure concentrations were used, these were averaged over various scenarios and time and still reflect an average value; additionally, the activity level (low, medium, or high) had a relatively small effect on the predicted risk. Finally, the activity-based sampling was conducted in public areas of El Dorado Hills that may not represent the highest NOA exposures that could be possible. The USGS studied mineralogy in the area and found that while the areas sampled in the activity-based sampling contained particles meeting regulatory definitions for asbestos, the most highly asbestiform particles came from other public locations [8]. Therefore, a specific individual could have significantly higher or lower exposure, depending on the particular areas he or she accessed during life.

The EPA 1986 method generally resulted in the highest predicted risk ranges, followed by the IRIS method and the Berman and Crump method. The Cal-EPA method predicted the lowest range of risk. This could be partially due to the fact that the Cal-EPA method only includes mesothelioma risk rather than mesothelioma plus lung cancer as in the other methods; however, a more likely explanation is the conversion factor used to convert total TEM concentrations to PCM being too high. If the Cal-EPA unit inhalation risk factors are used directly with PCMe data (an alternate application which has been used by U.S. EPA), the estimated risk is two orders of magnitude larger than the “official” method and slightly higher than the risk predicted using the EPA 1986 life table method. This would make more sense since the Cal-EPA unit risk was calculated more conservatively than the EPA unit risk.

Estimated lifetime risks using the methods listed in Table 4, including both background and activities, ranged from 1 in 100,000 (1×10^{-5}) to greater than 2 in 1,000 (2.2×10^{-3}). (As stated throughout this document, these risk estimates are highly uncertain and are only calculated to obtain a general idea of the degree of risk in the population.) For risk contributed by activities alone (not including background), the predicted risks ranged from 4 in 10,000,000 (4×10^{-7}) to 8 in 10,000 (8×10^{-4}).

These results do not allow us to predict with certainty the risk of developing asbestos-related cancers. The estimated ranges include risks from levels that would not be of concern to those that would be considered elevated above EPA’s range of acceptable risk for Superfund. This holds true for both background exposures and those resulting from outdoor activities.

ATSDR generally recommends that public health action be taken if exposures indicate the potential for an increased risk of cancer. While our findings have limitations, we believe it is prudent to inform the public about the potential risk and recommend public health actions to reduce potential exposures. Figure 5 presents suggested actions to minimize the potential for exposure to NOA; taking these public health actions will reduce the potential for harmful exposures to NOA and thus minimize the risk of disease occurring in the community.

Figure 5. Suggestions for Minimizing Community Exposure to NOA

Minimize Current Exposure to NOA:

- Wet areas with water prior to use to avoid stirring up dust that may contain NOA.
- Avoid the use of leaf blowers or compressed air.
- Drive slowly over unpaved roads, with windows and vents closed.
- Pave over or cover NOA-containing rock or soil, or cover with asbestos-free soil or landscape covering.
- Lower the amount of soil tracked into homes: use doormats, remove shoes, and clean pets' fur and feet.
- Keep buildings' and homes' windows and doors closed on windy days and during nearby construction.
- Use a wet rag instead of a dry rag or duster to dust; use a wet mop on non-carpeted floors.
- Use washable area rugs on floors and wash rugs regularly.
- Vacuum carpet often using a vacuum with a high efficiency HEPA filter, or steam clean.

Minimize Future Releases of NOA to Community Background:

- Document areas of known NOA
- Avoid uncontrolled disturbance of areas known or suspected to contain NOA
- Enforce state and local air regulations

For specific additional information targeted to workers and residents, see Appendix H.

"Background" Considerations

ATSDR evaluated risk including a value for background exposure in addition to activity-specific exposures. This was done to account for exposures occurring in places where the activity-based sampling was not performed, but where it is possible to be exposed to NOA disturbed through natural weathering or other activities not simulated in the sampling.

ATSDR's approach is consistent with EPA guidance stating that background should be considered in performing risk assessments [77,78]. Although background is a consideration, EPA risk assessments do not always include background in calculating risk from exposures—exposure may only occur intermittently at the site, or risk managers may decide to base cleanup decisions only on site-related exposure above background [79,80]. The inclusion of background concentrations contributed to estimated risk in our analysis. As indicated in Table 4, omitting background exposures reduced the low end of the risk range significantly; the high end of the risk range was reduced by a smaller amount.

Since background does contribute to overall predicted risk, we examined how the estimated background concentrations in El Dorado Hills compare with other locations in the United States. Knowledge about background asbestos concentrations in other locations is limited. ATSDR's toxicological profile summarizes various findings for ambient concentrations of asbestos in air. The profile cites studies finding that ambient outdoor air, remote from any special sources, contains 3×10^{-8} to 3×10^{-6} PCM f/cc; urban areas typically contained 3×10^{-6} to 3×10^{-4} PCM f/cc, but could reach up to 3×10^{-3} near local sources [13]. For comparison, this consultation used reference station data to estimate background concentrations of 4×10^{-4} PCM f/cc (wet periods) to 4×10^{-3} PCM f/cc (dry periods). Thus, the values for background in El Dorado Hills appear to be similar to high end typical urban environments or near local sources.

ATSDR does not know what every source is that contributes to the background concentrations in El Dorado Hills. We also do not know how much each of those sources contributes. Therefore, we believe it would be prudent to limit activities that could lead to increased background concentrations in the area.

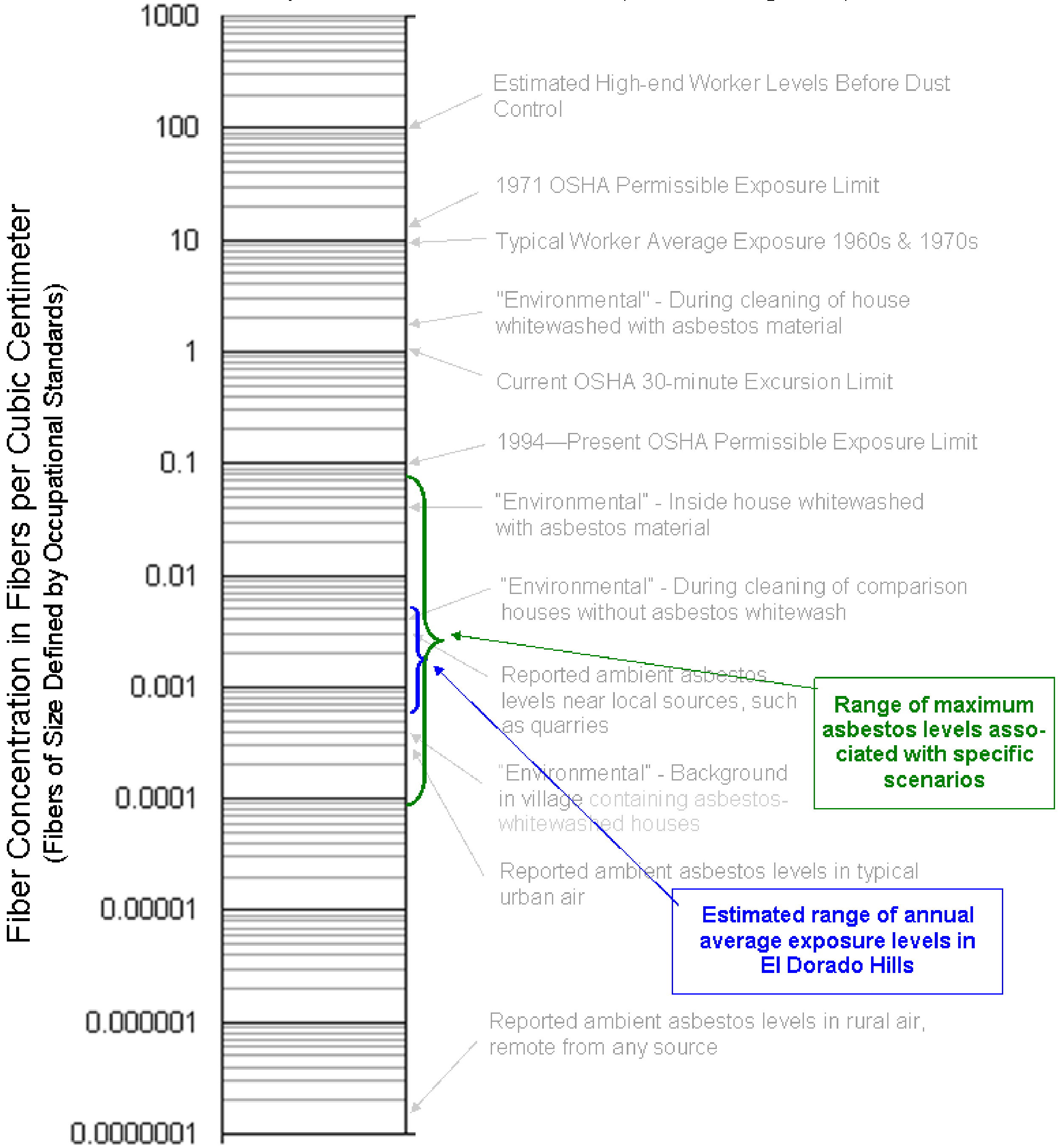
Is a Health Study Needed in the Community?

Under specific situations, health studies can describe the risk in developing a health condition or the likelihood that exposure and diseases are related. A health study typically does not determine if disease is caused by exposure. However, it is very unlikely that a health study in the El Dorado Hills area would provide new information not already known about NOA or potential health risks associated with NOA:

- First, we anticipate that the number of people who would develop disease caused by NOA would be very low. This is because the El Dorado Hills community's exposures are much lower than those measured and estimated in historical asbestos worker studies and are also lower than what limited exposure studies have suggested are present in other NOA communities where disease was found. See Figure 6, which shows the El Dorado Hills exposure estimates in relation to other occupational and nonoccupational exposure levels depicted earlier in Figure 4.
- Second, to assess the likelihood that exposure and disease are related there must be an accurate way to measure or estimate an individual's exposure to NOA. However, there is no reliable clinical method for measuring an individual's exposure, and the information people know about their exposure history to NOA would be too limited to make accurate estimates of exposure.
- Third, detecting asbestos-related conditions in the community would be further complicated by the fact that asbestos related conditions typically take decades to develop. Only within about the last 15 years has the area seen large increases in development and population. Therefore it is unlikely that health effects from asbestos exposure would have had sufficient time to develop. (As reported in ATSDR's health consultation on Oak Ridge High School in El Dorado Hills, the California Cancer Cancer Surveillance Program found no elevation in expected mesothelioma incidence rates for western El Dorado County from 1988-2001 [6].) Current medical testing would not detect health effects that may or may not develop later in life.

On the basis of these considerations, we do not recommend a health study. However, to monitor the community's health, ATSDR recommends that health statistics on asbestos-related conditions in the community be examined periodically to identify any unforeseen elevation in disease rates.

Figure 6. Comparison of El Dorado Hills Results with Occupational and Nonoccupational Asbestos Levels (Refer to Figure 4).



NOTE: This schematic illustrates where estimated and measured asbestos levels in El Dorado Hills fall as compared with occupational and nonoccupational levels from Figure 4. The estimates are placed on a "log" scale, which allows widely different values to be seen on the graph—each heavy line is a value ten times the next lower heavy line. The overall exposure any person receives is a function both of the level and the length of time for which the exposure continues.

Additional Information on NOA in the El Dorado Hills Area

The site-specific activity-based sampling data gave us the best information possible on actual exposures people in the community might experience, and applying risk methods gave us the best estimate of resulting excess cancer risk possible given the state of the science. However, as described earlier in the "uncertainties" section, measuring exposures and estimating risk for NOA-exposed communities involves a great deal of uncertainty. We heard concerns from community members and from stakeholders that the activity-based sampling may not have been representative of all possible exposures, that the various risk methods do not fully account for risk, and that other data from the local area may not agree with the activity-based sampling data. Therefore, we looked at other studies that have been done in the area to provide additional information and support to our conclusions from using activity-based sampling data to estimate risk. The following section describes these additional studies and discusses how their findings relate to the activity-based sampling results on which our risk estimates are based.

- The California Air Resources Board (CARB) conducted ambient monitoring for NOA at several locations, including several in El Dorado County, during the years 1998-2003. Results are available online [73]. Little information is given on the rationale for choosing locations for ambient monitoring, but it is likely that sampling was targeted to areas of concern or with a higher likelihood for having NOA. Documentation of the exact sampling conditions, including whether dust control measures were being used, was not available. Table 4 summarizes results for various locations in El Dorado County as downloaded from the CARB website and manipulated by ATSDR to determine statistics. Although average values are generally relatively low (nondetect values were counted as zero), levels detected varied widely both within a particular sample area and between various areas, indicating a potential for locally high asbestos levels under some conditions. (It should also be noted that CARB conducted ambient monitoring in other California areas; the statistics performed on those results (not shown) are similar to those presented in Table 4 for El Dorado County).

Table 4. Summary of California Air Resources Board Ambient Air Monitoring for NOA in El Dorado County *

Area Description (All Areas in El Dorado County)	Sampling Dates	# Detects / # Samples	Average ± Standard Deviation (total TEM s/cc)	95th Percentile (s/cc)	Maximum (s/cc)
El Dorado County, Various Sites	Apr-Oct 1998	57 / 252	0.001 ± 0.004	0.006	0.04
El Dorado County, Residences Near Quarry	Oct 1998	64 / 86	0.008 ± 0.02	0.03	0.1
El Dorado County, Quarry Entrance	Oct 1998	23 / 24	0.05 ± 0.05	0.1	0.2
Silva Valley, Various Sites	Apr 1999	5 / 35	0.0002 ± 0.0005	0.001	0.002
Garden Valley, Various Sites	Aug 1999	32 / 38	0.004 ± 0.004	0.008	0.02
Woedee Drive	Jan 2000	0 / 22	N/A†	N/A	N/A
Woedee Drive, Dirt Pile Removal	Feb 2000	0 / 8	N/A‡	N/A	N/A
Oak Ridge High School: Upper Soccer Field during mitigation	Jun-Jul 2003	62 / 85	0.0009 ± 0.0009	0.003	0.004
Oak Ridge High School: Lower Soccer Field during mitigation	Jun-Jul 2003	52 / 81	0.0006 ± 0.0006	0.002	0.002
Oak Ridge High School: Receptor Sites during mitigation	Jun-Jul 2003	26 / 58	0.0004 ± 0.0005	0.001	0.003

* Units are total TEM structures per cubic centimeter (s/cc) measured using AHERA definitions. Statistics were performed on all reported results for categories defined by CARB, applying a value of zero to nondetect results.

† Average detection limit 0.0009 s/cc

‡ Average detection limit 0.0008 s/cc

- In 1998, the Sacramento Bee newspaper reported findings of an industrial hygienist the newspaper had hired to study potential asbestos exposures in the El Dorado County area [1]. Various tests were performed in September 1997 at 3 houses: on Woedee Drive in El Dorado Hills (indoor dust and front yard air); on Wild Turkey Drive in Shingle Springs south of El Dorado Hills (indoor dust, front and back yard air, and along unpaved road); and on Cothrin Ranch Road in Shingle Springs (indoor dust). According to the newspaper report, the stationary air monitors showed no detectable asbestos or barely detectable levels of chrysotile asbestos. The monitor set up along the unpaved road while a vehicle passed by to simulate traffic showed an actinolite concentration of 0.22 fibrous structures per cc. (Although not explicitly stated, other information in the article implies that these analyses were performed according to AHERA-type procedures and thus include all structures greater than 0.5 μm in length – the values cannot be compared with standards based on PCM f/cc units.) Finally, indoor dust samples collected with a microvacuum from areas not regularly cleaned showed actinolite asbestos ranging from about 4,000—500,000 structures per square centimeter (s/cm^2); each home had at least one sample above 10,000 s/cm^2 [1]. For comparison, experts in this type of sampling have indicated that values below 1,000 s/cm^2 are generally not different from background, levels around

10,000 s/cm^2 may show an elevation above background, and levels around 100,000 s/cm^2 show a significant elevation, such as from a release of asbestos containing material [8282]. Also for comparison, in the World Trade Center test and clean program following the 9/11 tragedy, cleanup was performed if asbestos in dust exceeded 5,000 s/cm^2 for accessible areas or 50,000 s/cm^2 for infrequently accessed areas (like behind appliances) [82].

- Cal-EPA's Department of Toxic Substances Control (DTSC) performed a series of studies of potential exposure associated with unpaved roads in California. In El Dorado County, a study was performed in 2004 at Slodusty Road in the Garden Valley area near Coloma [5]. Air measurements were collected before and after resurfacing of a serpentine-covered road, and risks were estimated using the Cal-EPA method. Prior to resurfacing of the unpaved road, typical traffic patterns resulted in total asbestos structure concentrations ranging from 0.009–9.5 s/cc, depending on number of vehicles per hour, speed of the vehicles, and distance of the sample from the roadway. Resurfacing of the roadway significantly reduced asbestos release, reducing the maximum values by two orders of magnitude. The primary type of asbestos detected in this study was chrysotile.

- Oak Ridge High School in El Dorado County was one of the locations where CARB conducted ambient air monitoring (in 1998 and during mitigation of asbestos in 2003). Several additional sampling events took place at the school following the discovery of amphibole asbestos during construction of new soccer fields in 2002. Soil testing and active and passive air monitoring were conducted at various indoor and outdoor campus locations; sampling was primarily conducted by contractors of the school district and EPA. These studies, summarized in ATSDR's previous health consultation on Oak Ridge High School, indicated the potential for elevated exposure to asbestos, especially during outdoor athletic and maintenance activities [6]. At this time, most areas of the campus have had NOA mitigated.

- As part of the Air Toxics Control Measures, developers of construction sites containing NOA are required to conduct dust suppression and may be required to perform air monitoring. The El Dorado County Air Management District provided ATSDR with approximately one year of sampling data for a large construction site in the county [72]. ATSDR summarized the data as shown in Figures 7 (total TEM s/cc) and 8 (PCM f/cc). These data were used as partial support for our assumption of a 13-week "wet" period in which lower asbestos levels were detected, as indicated on each figure by the period where concentrations were an order of magnitude smaller.

Figure 7. Transmission Electron Microscopy Results at a Construction Site

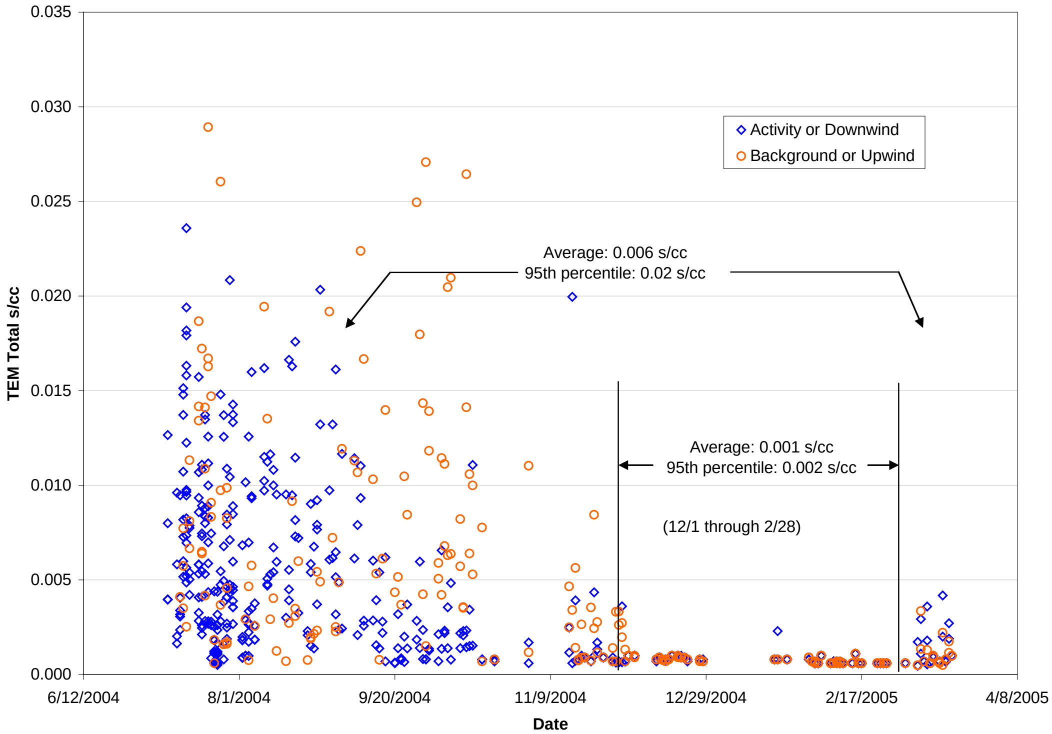
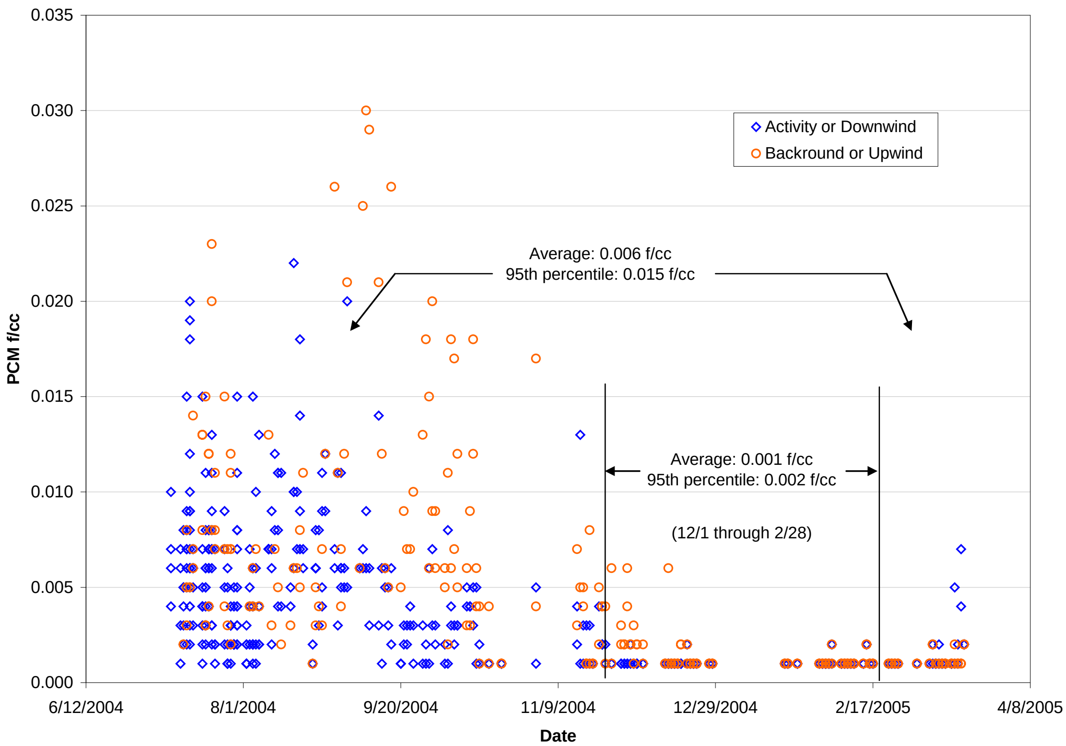


Figure 8. Phase Contrast Microscopy Results at a Construction Site



- In Fall 2005, the El Dorado Hills Community Services District conducted air sampling at several locations in the Community Service District parks and recreational areas. The sampling was a modified activity-based method in which raking was performed around a high-volume stationary monitor. Of 15 samples analyzed with TEM, the average total structure concentration was 0.007 s/cc and the maximum 0.02 s/cc [82]. These values are similar to those reported by the local developer shown in Figure 4, and they are also similar to the "average" values for total TEM s/cc in the activity scenarios evaluated in this consultation.

- Rescue Union School District conducted NOA sampling at the site of the Promontory Point Elementary School in 2005 [85]. "Upwind" and "downwind" stationary air monitoring results were similar, with average total structure concentrations of around 0.003 s/cc and a maximum of 0.03 s/cc. These values are also similar to the construction data, community services district data, and estimates used in this health consultation.

- In response to criticisms by an interested party that there should be no concern because the particles measured in EPA's sampling do not fit the definition of commercial asbestos, the EPA requested the USGS to characterize the mineralogical nature of NOA materials present around the El Dorado Hills area. USGS characterized mineralogy and morphology of asbestos-related structures in soil samples collected by USGS in the area in Spring 2006, and compared the findings with results from analysis of activity-based sampling filters collected by the EPA in Fall 2005. Soil samples showed actinolite, magnesio-hornblende, and tremolite amphibole particles, with morphologies ranging from prismatic and acicular to asbestiform. Regarding the particles measured by EPA during the activity-based sampling, the USGS reported that "many of the amphibole particles examined in this study meet the counting rule criteria used by USEPA from both chemical and morphological requirements. However, most of these particles do not meet the morphological definitions of commercial-grade asbestos". In other words, the EPA correctly counted asbestos particles according to accepted analytical procedures, even though the particles would not be considered asbestos per commercial definitions. The USGS cautioned, "Based on the current level of understanding in the asbestos community, it is not clear that toxicity strictly correlates with only the commercial or regulated forms of asbestos" [8]. As stated in the "Discussion of Risk Results" section on page 30, the USGS found that the particles that were the most asbestiform came from public locations where activity-based sampling was not conducted. From this, we infer that the activity-based sampling does not necessarily reflect the highest exposures possible in the community.

Taken in sum, these additional studies illustrate the potential for NOA to exist in several locations throughout the El Dorado Hills area. They also suggest that the levels measured in EPA's Fall 2004 activity-based sampling were typical of those that might be measured elsewhere in the local area.

Is the Situation in El Dorado County Unique?

ATSDR heard, many times, concerns from local stakeholders that they felt El Dorado Hills and El Dorado County were being "singled out" and subjected to an unfair level of scrutiny, given that NOA is present in many other areas of California and the country. They requested ATSDR to help put the NOA issue in El Dorado Hills in perspective by discussing other NOA sites and the actions taken at those sites. While every site is unique in the sense that particular exposure situations and the recommended public health actions may differ, we agree that western El Dorado County is not the only place where disturbance of NOA has arisen as a public health issue. We agreed to provide information on other NOA sites to illustrate the breadth of sites and areas that have had to deal with NOA issues and give examples of how the issues were addressed.

Actions taken will be different depending on the particular sites' characteristics and the local environment. We emphasize that the conclusions for the El Dorado Hills area are based on the site-specific exposure data collected, risk estimates made from those data, and other site-specific NOA studies (used qualitatively). The following information on other sites is provided for perspective only.

- Other counties in California and elsewhere are known to have NOA deposits. Several are like El Dorado County in that they have recognized a potential problem and instituted local ordinances or community outreach efforts to prevent exposures. These include Fairfax County in northern Virginia, and Lake and Placer counties in California [86–88]. CARB conducted air monitoring in Lake and Placer Counties; results were similar to those found by CARB in El Dorado county [73]. ATSDR is not aware of other air sampling or activity-based sampling efforts in these locations that could be compared with El Dorado County.

- ATSDR is aware of other communities potentially exposed to NOA materials where activity-based sampling was performed to assess exposure.
    - In Ambler, Alaska, ATSDR measured asbestos levels as high as 0.05 PCMe s/cc during ATV riding on NOA-contaminated gravel roads. The road material was brought into town from a local gravel pit which was contaminated with naturally occurring chrysotile asbestos. ATSDR determined that a health hazard was presented by road dust for both asbestos and particulate exposure. ATSDR recommended immediate cessation of use of the gravel for road cover, closure of the pit, development of short-term and long-term solutions to road-generated dust, mitigation of areas where children could contact contaminated soils, and community education [89].
    - Activity-based sampling was performed by EPA at Swift Creek, Washington. The contamination washed down a creek from a remote slow landslide of chrysotile-contaminated rock; contaminated material had been periodically dredged and stored on banks of the creek. EPA performed activity-based sampling in August 2006 for handling dredged material with heavy equipment, raking/shoveling, and recreational scenarios; results showed that the highest PCMe structure levels were for handling dredged material and ranged from 0.03–0.2 s/cc. The raking and

recreation scenarios had levels ranging from 0.009–0.09 s/cc [90]. Further work to characterize the extent of the NOA contamination downstream is ongoing.

- EPA conducted activity-based sampling at Clear Creek Management Area in California, a recreational area. The area includes the largest natural deposit of chrysotile asbestos in the U.S. Results of sampling showed that intense activities like ATV riding resulted in PCMe asbestos structure levels as high as 2 s/cc [79]. At this time, the Bureau of Land Management (BLM) has temporarily closed the area to all public use due to the exposure potential. The closure will remain in effect while the BLM completes a resource management plan to determine if and how visitor use can occur without the associated excess health risk [91].
- Activity-based sampling has been conducted by EPA in Libby, Montana, a town contaminated with amphibole asbestos from local mining and processing operations. Limited sampling collected in 2001 showed that outdoor activities like rototilling and indoor activities like cleaning could result in elevated levels of asbestos [92]. These samples were reanalyzed to achieve greater sensitivity, and additional samples were collected in 2005. Indoor cleaning activities were found to result in asbestos detections ranging from 0.0007-0.2 PCMe s/cc; indoor routine activity detections ranged from 0.00007-0.007 PCMe s/cc; and a limited number of outdoor activity samples had detections ranging from 0.03-0.2 PCMe s/cc [93]. Results of more extensive activity-based sampling in 2007 have not yet been released.
- EPA conducted activity-based sampling at Sapphire Valley Gem Mine in western North Carolina to assess the risk to occasional recreational visitors and gem collectors from amphibole (anthophyllite) asbestos present in the mine along with gemstones. Results of the sampling showed that the most intense activities, chipping at the rocks to release stones, resulted in PCMe asbestos structure levels as high as 0.29 s/cc. Risk was found to be above acceptable ranges only if a person engaged in such activities regularly for many years. The mine is privately owned. At the request of state health authorities, access to the mine has been restricted and limited by private actions [94].
- ATSDR and EPA conducted activity-based sampling at Illinois Beach State Park north of Chicago, Illinois to assess risk to recreational beach users from asbestos-containing materials washing up on the shore and possibly contaminating beach sand, with possible contribution from NOA. Asbestos levels were below detection in most samples and very low in others. ATSDR concluded that potential asbestos exposures at the park are not expected to harm people's health [95].

Conclusions

ATSDR reached 2 important conclusions in this health consultation:

Conclusion 1

Breathing in naturally occurring asbestos (NOA) in the El Dorado Hills area, over a lifetime, has the potential to harm people's health.

Basis for conclusion

- Background levels of NOA in El Dorado Hills are higher than asbestos levels measured in other non-urban and most urban environments. Activities that disturb NOA could result in levels higher than background.
- A general sense of the increased risk of developing cancer from breathing in asbestos throughout life was obtained using several different risk assessment methods with the results of EPA's activity based sampling in El Dorado Hills. For each method, a range of theoretical increased risks of developing cancer was estimated using different assumptions about how much and how often people breathed in NOA. Each risk method has considerable uncertainty, but the different risk methods gave similar results: the predicted increased risk of cancer ranged from too low to be of concern to a level high enough that action to prevent exposures would be warranted.
- Any one person could have markedly higher (or lower) exposures than the general estimates made in this report, depending on whether, how, and how often they encounter NOA in their daily activities.

Next steps

The following actions will reduce the likelihood for people to breathe NOA:

Increase Awareness

- El Dorado County should continue to assess the community's knowledge about the presence and associated risk of NOA and to provide information about ways to manage the risk. ATSDR can provide assistance, if requested.
- El Dorado County should implement, to the extent possible, effective ways to:
  - Maintain current records of locations known to contain NOA and
  - Notify current and prospective landowners of the possibility for NOA to exist in soil or bedrock on their property.

Limit Exposure

- State and local entities should continue to enforce applicable dust regulations throughout the community, which will reduce releases of NOA. For sites subject to asbestos hazard mitigation requirements, these regulations involve:
  - Prohibition of visible dust emissions outside the property line or more than 25 feet from the point of dust-disturbing activities,
  - Implementation of procedures to prevent vehicles and equipment from releasing dust or tracking soil off-site, and
  - Requirements for planning, notification, and record-keeping.
- Community members and groups should learn how to minimize their exposure to NOA while conducting their normal activities. ATSDR guidelines are included in Appendix H of this report.

Conclusion 2 A health study of the community of El Dorado Hills would not provide helpful information at this time.

Basis for conclusion

- It is very unlikely that a health study would provide additional information not already known about the presence of NOA or potential health risks from inhaling NOA:
  - Although theoretical risk was increased, potential exposures are generally orders of magnitude lower than those experienced by former asbestos workers. Potential exposures are also lower than what limited exposure studies have suggested are present in other NOA communities where disease was found. Therefore, we anticipate there would be very few cases of disease, if any, and the findings may not be generalizable to the community as a whole.
  - There is currently no reliable way to measure a particular person's exposure.
  - Even if exposures were high enough to cause disease, it takes decades for symptoms to appear. Therefore health conditions may not be detected at this time.
- A health study would not conclusively state that NOA caused a specific person's health condition.

Next Steps

- Although we do not expect observable increases in disease, state authorities should continue to monitor asbestos-related cancer incidence rates in the area as a means to monitor the community's health and to identify any unforeseen elevation.
- If community members feel their health has been affected by NOA, they should consult with their personal medical provider.
- ATSDR encourages further research on NOA exposures and community health by governmental and academic organizations. ATSDR may refine the conclusions and recommendations of this health consultation as results of ongoing asbestos research become available.

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References

1. Bowman C. “Pair gave up home over fear of asbestos,” “Couple’s tip led to tests, analysis: expert focused on asbestos from area serpentine,” “The asbestos danger,” “Projects in El Dorado churning up asbestos: potential cancer hazard in unearthed bedrock.” The Sacramento Bee 1998 March 29.

2. Van Gosen BS. The geology of asbestos in the United States and its practical applications. Environ Eng Geosci 2007; 9(1):55-68.

3. U.S. Environmental Protection Agency. Superfund Information Systems. Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Available on-line at: http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm. Accessed November 15, 2007.

4. Democrat Staff. “EPA paved rural subdivision’s serpentine roads in ’86: Garden Valley Ranch Estates action angered county Board of Supervisors.” The Mountain Democrat (Placerville, CA) 1998 April 1.

5. Department of Toxic Substances Control. Study of airborne asbestos from a serpentine road in Garden Valley, California. California. Sacramento: Department of Toxic Substances Control, California Environmental Protection Agency. April 2005.

6. Agency for Toxic Substances and Disease Registry. Health consultation on asbestos exposures at Oak Ridge High School, El Dorado Hills, California. Atlanta: U.S. Department of Health and Human Services; 2006.

7. U.S. Environmental Protection Agency. El Dorado Hills naturally occurring asbestos multimedia exposure assessment final preliminary assessment and site inspection report. San Francisco: U.S. Environmental Protection Agency, Region 9; 2006.

8. Meeker GP, Lowers HA, Swayze GA, Van Gosen BS, Sutley SJ, Brownfield IK. Mineralogy and morphology of amphiboles observed in soils and rocks in El Dorado Hills, California. U.S. Geological Survey Open-File Report 2006-1362. December 2006.

9. Frank AL. The history of the extraction and uses of asbestos. In: Dodson RF and Hammar SP, eds. Asbestos risk assessment, epidemiology, and health effects. Boca Raton: CRC Press, Taylor & Francis Group; 2006. pp 4-6.

10. Virta RL. Asbestos: Geology, Mineralogy, Mining, and Uses. USGS Open-File Report 02-149. http://pubs.usgs.gov/of/2002/of02-149/of02-149.pdf

11. Lowers and Meeker 2002. Tabulation of Asbestos-Related Terminology. USGS Open-File Report 02-458. http://pubs.usgs.gov/of/2002/ofr-02-458/OFR-02-458-508.pdf

12. Lemen RA. Epidemiology of asbestos-related diseases and the knowledge that led to what is known today. In: Dodson RF and Hammar SP, eds. Asbestos risk assessment, epidemiology, and health effects. Boca Raton: CRC Press, Taylor & Francis Group; 2006. pp 201-308.

13. Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos (update). Atlanta: U.S. Department of Health and Human Services; September 2001.

14. Wright RS, Abraham JL, Harber P, Burnett BR, Morris P, West P. Fatal asbestosis 50 years after brief high intensity exposure in a vermiculite expansion plant. Am J Respir Crit Care Med 2002;165:1145-1149.

15. Luo S, Liu X, Tsai SP, Wen CP. Asbestos related diseases from environmental exposure to crocidolite in Da-yao, China. I. Review of exposure and epidemiological data. Occup Environ Med 2003; 60:35-42.

16. U.S. Cancer Statistics Working Group. United States Cancer Statistics: 1999–2003 Incidence and Mortality Web-based Report. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute; 2007. Available at: www.cdc.gov/uscs Accessed October 22, 2007.

17. Centers for Disease Control and Prevention. Web page on lung cancer risk factors. Available at: http://www.cdc.gov/cancer/lung/basic_info/risk_factors.htm Accessed October 22, 2007.

18. Agency for Toxic Substances and Disease Registry. Health consultation on mortality from asbestosis in Libby, Montana for Libby Asbestos site. Atlanta, GA: U.S. Department of Health and Human Services. December 12, 2000.

19. Botha JL, Irwig LM, Strebel PM. Excess mortality from stomach cancer, lung cancer, and asbestosis and/or mesothelioma in crocidolite mining districts in South Africa. Am J Epi 1986;123(1):30-40.

20. Castellan, RM, Sanderson WT, Petersen MR. Prevalence of radiographic appearance of pneumoconiosis in an unexposed blue collar population. Am Rev Respir Dis 1985;131(5):684-686.

21. Peipins LA, Lewin M, Campolucci S, Lybarger JA, Miller A, Middleton D, Weis C, Spence M, Black B, Kapil V. 2003. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana. Environ Health Perspect: doi:10.1289/ehp.6346. [Online 2 July 2003]

22. Baris YI, Bilir N, Artvinli M, Sahin AA, Kalyoncu F, Sebastien P. An epidemiological study in an Anatolian village environmentally exposed to tremolite asbestos. Br J Ind Med 1988;45:838-840.

23. Rey F, Boutin C, Steinbauer J, Viallat JR, Alessandroni P, Jutisz P, DiGiambattista D, Billon-Galland MA, Hereng P, Dumortier P, DeVuyst P. Environmental pleural plaques in an asbestos exposed population of northeast Corsica. Eur Respir J 1993; 6:978-982.

24. Heller DS, Gordon RE, Clement PB, Turnnir R, Katz N. Presence of asbestos in peritoneal malignant mesotheliomas in women. Int J Gynecol Cancer 1999;9:452-455.

25. Fujiwara H, Kamimori T, Morinaga K, Takeda Y, Kohyama N, Miki Y, Inai K, Yamamoto S. An autopsy case of primary pericardial mesothelioma in arc cutter exposed to asbestos through talc pencils. Ind Health 2005;43:346-350.

26. Schneider J, Rodelsperger K, Bruckel B, Kleineberg J, Woitowitz HJ. Pleural mesothelioma associated with indoor pollution of asbestos. J Cancer Res Clin Oncol 2001;127:123-127.

27. Burdof A, Dahhan M Swuste PHJJ. Pleuramesothlioom bij vrouwen in verband gebracht met milieublootstelling aan asbest. [Pleural mesothelioma in women is associated with environmental exposure to asbestos]. Ned Tijdschr Geneeskd 2004; 148(35):1727-1731.

28. Dogan AU, Baris YI, Dogan M, Emri S, Steele I Elmishad AG, Carbone M. Genetic predisposition to fiber carcinogenesis causes a mesothelioma epidemic in Turkey. Cancer Res 2006; 66(10):5063-5068.

29. Luce D, Brochard P, Quenel P, Salomon-Nekiriai C, Goldberg P, Billon-Galland MA, Goldberg M. Malignant pleural mesothelioma associated with exposure to tremolite. The Lancet 1994; 344; 1777.

30. Paoletti L, Batisti D, Bruno C, DiPaola M, Gianfagna A, Mastrantonio M, Nesti M, Comba P. Unusually high incidence of malignant pleural mesothelioma in a town of eastern Sicily: an epidemiological and environmental study. Arch Environ Health 2000; 55(6): 392-393.

31. Sichletidis L, Daskalopoulou E, Tsarou V, Pnevmatikos I, Chloros D, Vamvalis C. Five cases of pleural mesothelioma with endemic pleural calcifications in a rural area in Greece. Med Lav 1992; 83, 4:326-329.

32. Occupational Safety and Health Administration (OSHA). OSHA Reference Method – Mandatory. 29 C.F.R. Sect. 1910.1001 Appendix A. OSHA Reference Method – Mandatory.

33. HM Factory Inspectorate. Standards for asbestos dust concentration for use with the asbestos regulations 1969, technical data note 13. England: Her Majesty's Stationery Office. 1969.

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

35. Millette JR. Asbestos analysis methods. In: Dodson RF and Hammar SP, eds. Asbestos risk assessment, epidemiology, and health effects. Boca Raton: CRC Press, Taylor & Francis Group; 2006. pp 9-37.

36. U.S. Environmental Protection Agency (Perry A). A discussion of asbestos detection techniques for air and soil. Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

37. U.S. Environmental Protection Agency. Asbestos Hazard and Emergency Response Act (AHERA). Appendix A to Subpart E – Interim Transmission Electron Microscopy Analytical Methods, U.S. EPA, 40 CFR Part 763, Asbestos-Containing Materials in Schools, Final Rule and Notice, 1987.

38. International Organization for Standardization. ISO 10312:1995. Ambient air – determination of asbestos fibres – direct transfer transmission electron microscopy method. 1995.

39. British Geological Survey. 2007. World Mineral Production 2001-05. Keyworth, Nottingham: British Geological Survey.

40. Pan X, Day HW, Wang W, Beckett LA, Schenker MB. Residential proximity to naturally occurring asbestos and mesothelioma risk in California. Am J Respir Crit Care Med 2005 Oct 15;172(8)"1019-1025. Epub 2005 Jun 23.

41. Comba P, Gianfagna A, Paoletti L. Pleural mesothelioma cases in Biancavilla are related to a new fluoro-edenite fibrous amphibole. Arch Env Health 2003; 58(4):229-232.

42. Emri S, Demir A, Dogan M, Akay H, Bozkurt B, Carbone M, Baris I. Lung diseases due to environmental exposures to erionite and asbestos in Turkey. Toxicology Letters 2002; 127:251-257.

43. Van Gosen BS. Reported Historic Asbestos Mines, Historic Asbestos Prospects, and Natural Asbestos Occurrences in the Eastern United States. U.S. Geological Survey Open-File Report 2005-1189. Version 2.0, posted March 2006. Accessed on April 29, 2008 at: http://pubs.usgs.gov/of/2005/1189/.

44. Van Gosen BS. Reported Historic Asbestos Prospects and Natural Asbestos Occurrences in the Central United States. U.S. Geological Survey Open-File Report 2006-1211. Version 1.0, posted August 2006. Accessed on April 29, 2008 at: http://pubs.usgs.gov/of/2006/1211/.

45. Van Gosen BS. Reported Historic Asbestos Mines, Historic Asbestos Prospects, and Natural Asbestos Occurrences in the Rocky Mountain States of the United States (Colorado, Idaho, Montana, New Mexico, and Wyoming) U.S. Geological Survey Open-

File Report 2007–1182. Version 1.0, posted July 2007. Accessed on April 29, 2008 at: http://pubs.usgs.gov/of/2007/1182/.

46. Van Gosen BS. Reported Historic Asbestos Mines, Historic Asbestos Prospects, and Natural Asbestos Occurrences in the Southwestern United States (Arizona, Nevada, and Utah) U.S. Geological Survey Open-File Report 2008–1095. Version 1.0, posted March 2008. Accessed on April 29, 2008 at: http://pubs.usgs.gov/of/2008/1095/.

47. California Geological Survey. A General Location Guide for Ultramafic Rocks in California - Areas More Likely to Contain Naturally Occurring Asbestos, 2000, Map scale 1:1,100,000. Open-File Report 2000-19. Sacramento, CA: California Department of Conservation. 2000.

48. California Geological Survey. Areas more likely to contain natural occurrences of asbestos in western El Dorado County, California. Open-file report 2000-02. Sacramento, CA: California Department of Conservation. May 2000.

49. Byrd and Cothern. 2000. Introduction to Risk Analysis. Government Institutes. 433 pg.

50. National Cancer Institute. SEER cancer statistics review 1975-2006, Table 1.14, lifetime risk of being diagnosed with cancer by site and race/ethnicity, 2004-2006.

51. Cooper MA. Medical aspects of lightning, how big a problem is this? Statistics. National Weather Service Fact Sheet, available at http://www.weather.gov/os/lightning/medical.htm

52. EPA. 1991. OSWER Directive 9355.0-30. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. http://www.epa.gov/oswer/riskassessment/baseline.htm

53. Covello VT, Sandman PM, Slovic P. Risk communication, risk statistics, and risk comparisons: a manual for plant managers. Washington, DC: Chemical Manufacturers Association, 1988.

54. National Safety Council. The odds of dying from… Fact Sheet available at http://www.nsc.org/research/odds.aspx

55. Scorecard: The Pollution Information Site. Website sponsored by Green Media Toolshed, available at www.scorecard.org. Accessed on October 23, 2008.

56. Murphy L, Schwartz TA, Helmick CG, Renner JB, Tudor G, Koch G, Dragomir A, Kalsbeek WD, Luta G, Jordan JM. Lifetime risk of symptomatic knee osteoarthritis. Arthritis Rheum. 2008 Sep 15;59(9):1207-13.

57. National Center for Health Statistics. Worktable 13R. Age-adjusted death rates for 358 selected causes: United States, 1999-2004. Centers for Disease Control, National Center

for Health Statistics. Table GMWK13R downloaded from http://www.cdc.gov/nchs/datawh/statab/unpubd/mortabs.htm on October 24, 2008.

58. U.S. Environmental Protection Agency (Nicholson WJ). Airborne asbestos health assessment update. Washington: U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, June 1986. EPA/600/8-84/003F.

59. Hodgson JT, Darnton A. The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure. Ann Occup Hyg 2000;44(8):565-601.

60. Berman DW, Crump KS. Final draft: technical support document for a protocol to assess asbestos-related risk. Prepared under contract to the U.S. Environmental Protection Agency. Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, October 2003. OSWER Directive # 9345.4-06.

61. Eastern Research Group. Report on the peer consultation workshop to discuss a proposed protocol to assess asbestos-related risk. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Lexington, MA: May 30, 2003. Available online at: http://www.epa.gov/oswer/riskassessment/asbestos

62. California Environmental Protection Agency. 2003. The Air Toxics Hot Spots Program Guidance manual for Preparation of Health Risk Assessments. Oakland: California Environmental Protection Agency, Office of Environmental Health Hazard Assessment.

63. California Environmental Protection Agency. 2001. Final Regulation Order: Asbestos Airborne Toxic Control Measure for Construction, Grading, Quarrying, and Surface Mining Operations. Section 93105. Adopted July 26, 2001.

64. U.S. Environmental Protection Agency. Science Advisory Board (SAB) webpage for OSWER Interim Method to Assess Asbestos-Related Carcinogenic Risk Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, webpage accessed October 8, 2008. Available online at: http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/f2a5dbfe31ffa9588525701a005896d3!OpenDocument&TableRow=2.0#2.

65. U.S. Environmental Protection Agency. Notice of public meeting: science advisory board meeting to review the proposed approach for estimation of bin-specific cancer potency factors for inhalation exposure to asbestos. Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, webpage accessed October 27, 2008. Available online at: http://www.epa.gov/oswer/riskassessment/asbestos/2008.

66. Science Advisory Board Asbestos Committee. SAB consultation on EPA's *Proposed Approach for Estimation of bin-specific cancer potency factors for inhalation exposure to asbestos.* Prepared for the U.S. Environmental Protection Agency. Washington, DC: November 14, 2008. Available online at:

http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/f2a5dbfe31ffa9588525701a005896d3!OpenDocument&TableRow=2.3#2.

67. Berman DW, Crump KS. Update of potency factors for asbestos-related lung cancer and mesothelioma. Crit Rev Toxicol 2008;38(S1):1-47.

68. Berman DW, Crump KS. A meta-analysis of asbestos-related cancer risk that addresses fiber size and mineral type. Crit Rev Toxicol 2008;38(S1):49-73.

69. Thun MJ, Day-Lally C, Myers DG, Calle EE, Flanders WD, Zhu BP, Namboodiri MM, Heath CW. Trends in tobacco smoking and mortality from cigarette use in Cancer Prevention Studies I (1959-1965) and II (1982-1988). In: National Cancer Institute, Smoking and Tobacco Control, Monograph 8: Changes in Cigarette-Related Disease Risks and Their Implicaton for Prevention and Control. Washington, DC: National Institutes of Health, 1997. NIH Publication No. 97-4213,305-382.

70. Centers for Disease Control. MMWR Weekly: Cigarette smoking among adults, United States, 2003. Issue May 27, 2005 / 54(20);509-513. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5420a3.htm

71. Monthly averages for El Dorado Hills, CA. Accessed on January 31, 2007 at http://www.weather.com/weather/wxclimatology/monthly/graph/USCA0335?from=search

72. Network Environmental Systems (NES). Naturally Occurring Asbestos Air Sampling Report. Folsom, CA: Network Environmental Systems, Inc. Prepared for Christopherson Homes, Incorporated, Promontory Village No. 4, El Dorado Hills, California. April 2005.

73. Cal-EPA (California Environmental Protection Agency). Naturally-occurring Asbestos – Air Monitoring. (Results from various counties, collected between 1999-2003). Cal-EPA, Air Resources Board. Accessed on April 3, 2008 at: http://www.arb.ca.gov/toxics/asbestos/airmon.htm.

74. U.S. Surgeon General. Bone Health and Osteoporosis: a Report of the Surgeon General. Chapter 7: Lifestyle Approaches to Promote Bone Health. Washington DC: Department of Health and Human Services. 2004. Accessed on January 25, 2007 at http://www.surgeongeneral.gov/library/bonehealth/content.html.

75. National Center for Health Statistics. Worktable 210R. Death rates for 113 selected causes, alcohol-induced causes, drug-induced causes, and injury by firearms, by 5-year age groups, race, and sex: United States, 2003. Centers for Disease Control, National Center for Health Statistics. Table GMWK210R downloaded from http://www.cdc.gov/nchs/datawh/statab/unpubd/mortabs.htm on August 21, 2007.

76. National Center for Health Statistics. LEWK3, United States life tables, 1999-2003, LEWK3_2003 (2003 data). Centers for Disease Control, National Center for Health

Statistics. Table LEWK3_2003 downloaded from http://www.cdc.gov/nchs/datawh/statab/unpubd/mortabs/lewk3_10.htm on October 14, 2008.

77. Cook MB. Memo to Superfund National Policy Managers, Regions 1-10 of U.S. Environmental Protection Agency RE: Transmittal of Policy Statement "Role of Background in the CERCLA Cleanup Program. OSWER 9285.6-07P. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, May 1, 2002. Available at: http://www.epa.gov/oswer/riskassessment/pdf/bkgpol_jan01.pdf

78. U.S. Environmental Protection Agency. Framework for investigating asbestos-contaminated Superfund sites, OSWER Directive #9200-068. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, September 2008. Available at: http://earth1.epa.gov/superfund/health/contaminants/asbestos/pdfs/framework_asbestos_guidance.pdf

79. U.S. Environmental Protection Agency. Clear Creek Management Area asbestos exposure and human health risk assessment. San Francisco, CA: U.S. Environmental Protection Agency, Region 9, May 2008.

80. Wroble J. Memo to Denise Baker-Kircher of U.S. Environmental Protection Agency RE: Risk Evaluation for Activity-based Sampling Results, Swift Creek Site, Whatcom County, Washington. Seattle, WA: U.S. Environmental Protection Agency, Region 10, February 8, 2007.

81. Eastern Research Group. Report on the expert panel on Biomarkers of asbestos exposure and disease, May 9-10, 2006. Prepared for the Agency for Toxic Substances and Disease Registry. Lexington, MA: Eastern Research Group. September 19, 2006. Available at: http://www.atsdr.cdc.gov/asbestos/asbestos/biomarkers_asbestos/docs/Biomarkers%20of%20Asbestos%20Meeting%20Summary_9-19-06-2_final.pdf

82. Millette JR and Hays SM. Settled asbestos dust sampling and analysis. Boca Raton: CRC Press, 1994.

83. U.S. Environmental Protection Agency. Lower Manhattan test and clean program, final report. New York: U.S. Environmental Protection Agency, Region 2, and New York City Response and Recovery Operations. November 2008.

84. Network Environmental Systems (NES). Naturally Occurring Asbestos Air Sampling Report, El Dorado Hills Community Services District, Community Park Softball Fields and Recreation Areas, El Dorado Hills, California. Folsom, CA: Network Environmental Systems, Inc. Prepared for El Dorado Hills Community Services District, El Dorado Hills, California. February 2006.

85. Hazard Management Services. Promontory Point Elementary School Air Sampling Data, November 4, 2003 – June 24, 2004. Rocklin, CA: Hazard Management Services, Inc. Prepared for Rescue Union Elementary School District, Rescue, CA. Transmittal letter dated March 9, 2005.

86. Fairfax County Health Department [homepage on the Internet]. Naturally Occurring Asbestos Documents. [accessed April 25, 2008]. Available from: http://www.fairfaxcounty.gov/hd/asb/downloads.htm.

87. Lake County Air Quality Management District [homepage on the Internet]. Asbestos. [accessed April 25, 2008]. Available from: http://www.lcaqmd.net/SerpentineAsbestosChoices.htm.

88. Placer County Air Pollution Control District [homepage on the Internet]. Naturally Occurring Asbestos General Information. [accessed April 25, 2008]. Available from: http://www.placer.ca.gov/Departments/Air/NOA.aspx.

89. Agency for Toxic Substances and Disease Registry. Exposure Investigation Final Report, Ambler Gravel Pit, Ambler, Alaska. Atlanta, GA: U.S. Department of Health and Human Services. June 28, 2007.

90. U.S. Environmental Protection Agency. Summary report of EPA activities, Swift Creek asbestos site, Whatcom County, Washington. Seattle, WA: U.S. Environmental Protection Agency, Region 10, February 2007.

91. Notice of closure to all forms of entry and public use of approximately 31,000 acres of public lands within the Clear Creek Management Area (CCMA), referred to as the Serpentine Area of Environmental Concern (ACEC) and portions of adjacent BLM-administered lands, located in southern San Benito County and western Fresno County, California. Federal Register 2008 May 1;73(85):24087-24088. Available online at: http://www.blm.gov/ca/st/en/info/fed_reg_archives/2008/may_2008/ccma_closure.html Accessed November 21, 2008.

92. Weis CP. Memo to P. Peronard of U.S. Environmental Protection Agency RE: Amphibole mineral fibers in source materials in residential and commercial areas of Libby pose an imminent and substantial endangerment to public health. Denver: U.S. Environmental Protection Agency, Region 8, December 20, 2001.

93. U.S. Environmental Protection Agency. Summary report for data collected under the supplemental remedial investigation quality assurance project plan (SQAPP) for Libby, Montana. Denver, CO: U.S. Environmental Protection Agency, Region 8, October 2007.

94. Agency for Toxic Substances and Disease Registry. Health consultation, Sapphire Valley Gem Mine naturally occurring asbestos site, Jackson County, North Carolina. Prepared by the North Carolina Department of Health and Human Services under a cooperative

agreement with the Agency for Toxic Substances and Disease Registry. Atlanta, GA: U.S. Department of Health and Human Services. September 18, 2009.

95. Agency for Toxic Substances and Disease Registry. Health consultation, evaluation of asbestos exposures at Illinois Beach State Park, Zion, Lake County, Illinois, release for public comment. Atlanta, GA: U.S. Department of Health and Human Services. March 10, 2009.

96. Selvin S. Statistical Analysis of Epidemiologic Data, Third Edition. New York: Oxford University Press; 2004.

97. U.S. Environmental Protection Agency. Guidelines for cancer risk assessment. Washington: U.S. Environmental Protection Agency. EPA/630/P-03/001F. March 2005. Available online at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=116283

Glossary

Important Note: *As we have tried to convey in the text of this report, the scientific community has not reached consensus on many terms related to asbestos. We provide the following suggested definitions and information as guidelines and illustration of what we mean in this report. We anticipate that many scientists and non-scientists will not agree fully with all of our definitions – and we would caution others against using these definitions unquestioningly. However, they do illustrate ATSDR's best effort to explain technical terms in ways that are helpful to the public.*

Acicular – A description of particle shape or *morphology*, literally "needle-like." This term is used most often to describe particles that are long and thin, but may not show the flexibility typically associated with a more fibrous shape.

Actinolite – A type of asbestos in the amphibole class. Actinolite was mined and used commercially in relatively limited quantities.

Amosite – A type of asbestos in the amphibole class. Amosite, also known as "brown asbestos," is named for the **A**sbestos **M**ines **O**f **S**outh Africa which contained many of the commercial mines.

Amphibole – Amphiboles are a group of widely distributed rock-forming magnesium-iron-silicate minerals. Certain amphiboles exist in a highly fibrous form and include 5 commerical varieties of asbestos: actinolite asbestos, amosite, anthophyllite asbestos, crocidolite, and tremolite asbestos.

Anthophyllite – A type of asbestos in the amphibole class. Anthophyllite was mined and used commercially in relatively limited quantities

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Asbestiform – A description of particle shape and characteristics, referring to fibrous particles that also show characteristics such as durability/nonreactivity, high aspect ratios, high tensile strength, nonconductivity, etc. See *morphology*.

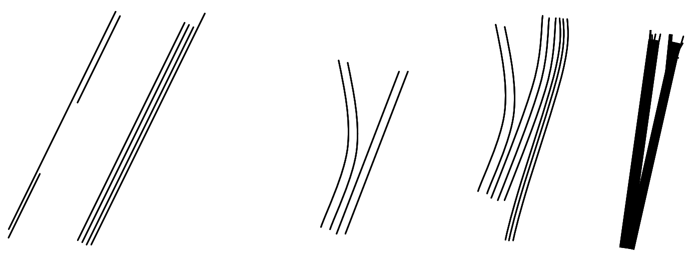
Asbestos – Asbestiform varieties of six specific minerals, historically mined for commercial use: actinolite, anthophyllite, amosite, chrysotile, crocidolite, and tremolite. It should be noted that different types of asbestos and even different samples of the same type may have notable differences in properties such as strength, flexibility, or average aspect ratio.

Asbestosis – A noncancerous disease caused by breathing in large amounts of asbestos. Asbestos fibers lodge within the lung, resulting in scar tissue formation which reduces lung elasticity and function. The disease progresses, typically slowly, and can eventually be fatal.

Asbestos-related disease – A disease that may be caused by breathing asbestos or another durable mineral particle that behaves like asbestos. Asbestos-related diseases include asbestosis, lung cancer, pleural disease, and mesothelioma.

Aspect ratio – A number describing the shape of a particle obtained by dividing the length by the width. Asbestos counting rules typically dictate a minimum aspect ratio of 3:1 or 5:1 to define a fiber; commercial asbestos has been reported to consist mostly of fibers with aspect ratios greater than or equal to 20:1.

Bundle – A type of asbestos structure counted by certain microscopic methods. The International Standards Organization defines a bundle as "a grouping composed of apparently attached parallel fibers." The aspect ratio of the bundle may have any value, as long as the individual fibers making it up have aspect ratios equal to or greater than 3:1 or 5:1, as defined by the particular method used.



Bundles

Chrysotile – A type of asbestos, the only type in the serpentine class. Chrysotile, also known as "white asbestos," was and remains the major type of asbestos used commercially.

Cleavage fragment – A piece of mineral broken off of a larger chunk, usually along a line of weaker bonds known as a "cleavage plane". A cleavage fragment may have the same *elemental composition* as an asbestos fiber but has a different *crystal structure*. A group of cleavage fragments are generally shorter and thicker than a group of asbestos fibers, but identifying any single structure as fiber or cleavage fragment can be difficult because some cleavage fragments meet size and shape definitions for fibers.

Cluster – A type of asbestos structure counted by certain microscopic methods. The International Standards Organization defines a cluster as "an aggregate of two or more randomly oriented fibers, with our without bundles." Clusters can be disperse, such that individual fibers or bundles can be identified and measured, or compact, where dimensions of individual fibers and bundles cannot be unambiguously determined.

Disperse (left) and Compact (right) Clusters

Crocidolite – A type of asbestos in the amphibole class. Crocidolite, also known as "blue asbestos" was commercially mined and used in many products including gas masks and cigarette filters.

Crystal – A homogeneous, three-dimensional solid formed by specific repeating atoms or molecules, with smooth external faces.

Crystal structure – The particular pattern of distances and angles between constituent units in a crystal, which can uniquely identify the crystal.

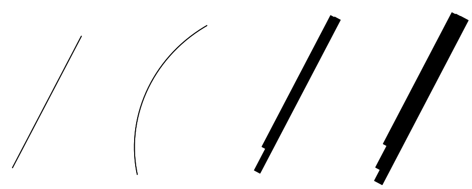
Cubic Centimeter (cc) – a unit of volume represented by a cube 1 centimeter long on each side, equivalent to a milliliter. So, for example, a bottle of wine would contain 500 cubic centimeters.

Electron microscopy – A way to visualize very small things by examining interaction of the item with an electron beam. Allows very high magnifications – to the atomic scale.

Elemental composition – Identification of a mineral's chemical makeup, as opposed to its physical characteristics [see *morphology*].

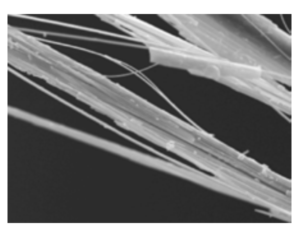
Fiber per cubic centimeter (f/cc) – Measurement of asbestos fiber concentration in air. The f/cc units are typically reported for phase contrast microscopy results, and include all particles that meet dimensional criteria for fibers as defined by the method. [see also *s/cc*]

Fiber – In general, fiber refers to any long, thin, and thread-like particle. Asbestos includes many fibers. In microscopic methods for measuring asbestos, fiber refers to a particle meeting dimensional criteria set by the method for counting fibers. The criteria typically include parallel or stepped sides, a minimum *aspect ratio* (3:1 or 5:1) and, in some cases, specific length and/or width requirements.



Fibers

Fibril – A very thin fiber which often can make up a larger fiber, like individual nylon threads that make up a rope.



Electron micrograph showing fibrils of asbestos making up larger fiber/bundle.

Fibrotic disease – Refers to respiratory disease resulting from buildup of fibers in the lungs, which can lead to scarring and other lung problems.

Fibrous – A description of particle shape, referring to long, thin, thread-like shapes. See *morphology*.

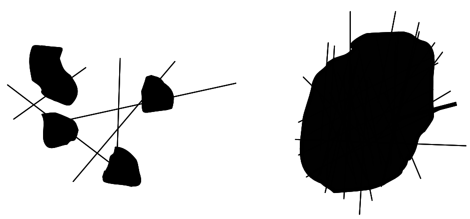
Latency – The time lag between a disease-inducing event and the development of the disease itself. Asbestos diseases have long latency – symptoms of disease may not appear until many years after the exposure.

Lung cancer – A disease where the epithelial cells lining the lung grow out of control. They may invade surrounding tissues or move (metastasize) to cause cancer in other tissues in the body. Breathing in asbestos is one of many potential causes of lung cancer.

Macroscopic – Able to be seen with the naked eye.

Massive – Refers to minerals that have the same crystal structure and physical properties in all directions, that is, they don't have a platy, fibrous, or other structure that varies directionally.

Matrix – A type of asbestos structure counted by certain microscopic methods. The International Standards Organization defines a matrix as a structure in which one or more fibers or fiber bundles are attached to, or partially concealed by, a single particle or group of overlapping nonfibrous particles. Special rules apply for counting matrices and depend on whether the matrix is disperse (where at least one individual fiber can be discerned and measured) or compact (where individual fibers cannot be measured).



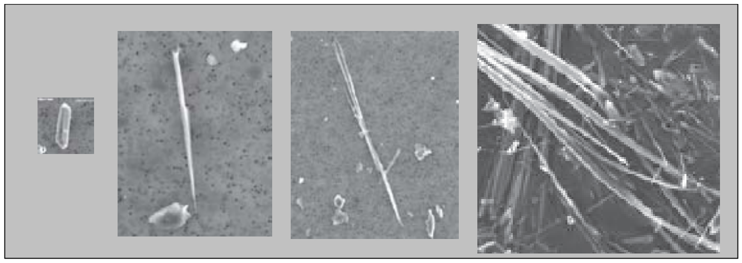
Disperse (left) and Compact (right) Matrices

Mesothelioma – A cancer of the mesothelium, the membrane surrounding internal organs like the lung (pleural mesothelium), digestive organs (peritoneal mesothelium), or heart (cardial mesothelium). Mesothelioma is a very rare cancer, but in almost all cases is associated with exposure to asbestos or a similar durable mineral fiber.

Micrometer (or micron, μm) – A unit of length measuring one one-millionth of a meter, or about the size of a bacteria. The smallest line a human eye can see is about 30 μm – ¼ to ½ the width of a typical human hair.

Microscopic – Too small to be seen with the naked eye. Requiring a microscope to see.

Morphology – In contrast to *elemental composition*, identification of a mineral by its size, shape, and *crystal structure* (e.g., physical characteristics).



Electron Micrographs from the US Geological Survey illustrating particle morphologies, from left to right, prismatic, acicular, fibrous, and asbestiform. The images were manipulated to put them on the same scale.

Million particles per cubic foot (mppcf) – A measure of particle concentration in air. Early dust measurements in the asbestos industry were collected using an apparatus called a midget impinger, whose results were in units of mppcf.

Nonfibrous – Referring to particles that do not exhibit the long, thin, thread-like shape associated with fibrous particles; can include *acicular* and *prismatic* particles.

Optical microscopy – A way to visualize very small things using light with magnifying lenses. Limited in resolution to about 0.25 μm.

Pleural changes –Abnormalities observed in the pleural mesothelium, the membrane lining the chest cavity and covering the outside of the lungs. Pleural changes can include areas of pleural thickening, calcification (plaques), or pleural effusions (accumulation of liquid in the pleural space). Pleural changes resulting from asbestos exposure are typically observed bilaterally (on both sides of the chest) and may or may not result in a loss of lung function.

Polymer – A substance made up of smaller, repeating molecules.

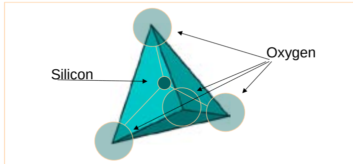
Prismatic – A description of particle shape and characteristics, referring to blocky particles with relatively low aspect ratios, similar to crystal forms which have faces parallel to the vertical axis. See *morphology*.

Progressive disease – A disease that gradually gets worse over time.

Structures per cubic centimeter (s/cc) - Measurement of asbestos concentration, referring to number of asbestos structures per cubic centimeter of air. This measurement is typically used for electron microscopic methods and includes the count of asbestos *fibers* as well as asbestos *bundles*, *clusters*, and *matrices* as defined by the method. [see also *f/cc*]

Serpentine – A type of rock originally formed from high-magnesium source rocks [see *ultramafic*]. Serpentine can exist in a highly fibrous form, chrysotile asbestos.

Silica tetrahedron – The molecular "backbone" of asbestos, consisting of the elements silicon and oxygen bonded in the shape of a tetrahedron (a pyramid-like structure formed by 4 triangles).



Silica tetrahedron

Silicate – A mineral containing a silicate molecule, containing the elements silicon and oxygen, as its major "backbone" material. Silicates form the largest class of rock-forming minerals. Examples of silicate minerals include talc, quartz, emerald, and asbestos.

Structure – A microscopic term including asbestos *fibers* and associated particles such as *bundles*, *clusters*, and *matrices* as defined by the analytical method used.

Tremolite asbestos – A type of asbestos in the amphibole class. Tremolite asbestos was rarely mined commercially, but is often a contaminant in chrysotile asbestos, vermiculite, or other mined products.

Ultramafic – A type of igneous rock (formed by cooling of lava) containing high levels of magnesium and iron. Under certain conditions, ultramafic rocks can be changed (metamorphized) into rocks that may host asbestos. This process takes millions of years.

Appendix A. Peer Review Comments and Responses

Many issues in asbestos science today are debated among scientists. ATSDR requested a draft of this public health consultation be "peer reviewed" to ensure that the evaluation performed in the document was done using the best science given the nature of the available information. The public health consultation was peer reviewed by three asbestos science experts who have no affiliation with ATSDR and are listed below. This appendix contains the questions posed to the peer reviewers, their comments (verbatim), and ATSDR's responses to the comments. The comments from peer reviewers are labeled #1, #2, and #3 but these numbers do not necessarily correspond to the order the reviewers are listed below.

Peer reviewers:

Robert (Bob) French
Professional Engineer
EHS-Alaska

Paul J. Lioy
Professor of Environmental and Community Medicine
Rutgers University, Robert Wood Johnson Medical School

Morton Lippmann
Professor of Environmental Medicine
New York University School of Medicine

1. Does the health consultation provide adequate background information for the lay public to understand the potential for concern about community exposures to naturally occurring asbestos in the El Dorado Hills area?

[Comments from Reviewer #1]:

Yes.

[Comments from Reviewer #2]:

Yes, the outline and the format of the evaluation provide a good background for the issue at hand. The summary of the various risk assessment tools used are confusing and do not provide enough information to help convey the meaning of the results to the community.

I think you need to break down the issue into what does a 1/10,000 or 1/1000 risk mean to a community of the size of El Dorado Hills with a population of 35,000 that cuts across a wide range of ages and time spent living in the community. There also should be a statement that none of these methods are without uncertainties and the results are used for guidance and not the prediction of actual number of cases of Asbestos related disease.

[Comments from Reviewer #3]:

I feel that some terms and background information should have additional explanations. For example, on Pg 7, there could be a discussion of what disease latency is, and typical latency periods for various asbestos related diseases, as latency is brought up on Pg 8 without an explanation of what it means.

Many lay persons do not have an intuitive feel for the tiny sizes involved in microscopic particles, and metric units, therefore on Pg 9, a discussion of micrometers, cc's, structures versus fibers, fiber morphology etc. would be helpful. On page 11, technical terms such as "cleavage fragments", "acicular", "massive" (perhaps blocky is a better term), "asbestiform", "nonfibrous", could use additional descriptions, perhaps examples could be illustrated with the TEM photographs from the USGS report OF06-1362.

A discussion of how past worker exposures (that are the basis of epidemiological data) may be at least an order of magnitude higher than the potential community exposures, and the difficulties and uncertainties of extrapolating past exposure data would also be useful. See related comments in item 2 below. While the consultation does qualitatively discuss this ("much less", "well below"), examples of actual exposure data would help the public understand the relative exposures, and give a perspective on the relative risks.

Q#1 – Response from ATSDR: *ATSDR has responded to the peer reviewers' concerns by making the following additions to the health consultation:*

- *Figure 4 was added to illustrate typical asbestos exposure levels, workplace standards and background levels in a visual, semi-quantitative form. This figure is later re-introduced and modified as Figure 6, showing where the asbestos levels estimated for El Dorado Hills fall.*
- *The addition of a glossary (on page 55, following the references) to give further explanation for technical terms and measurements used in the document.*
- *Addition of section describing general concepts of risk on page 14, before the introduction of asbestos risk assessment methods. The comparisons of risk previously found at the end of the text has been revamped and moved forward into this section as well.*

We hope these additions improve the readability and clarity of the technical information we want to convey to the public.

2. Does the health consultation clearly describe the purpose for applying various risk assessment methods to estimated community exposures? Does the text maintain objectivity when describing differences between current and proposed risk assessment methods?

[Comments from Reviewer #1]:

Yes.

[Comments from Reviewer #2]:

This is a rather confusing statement. I assumed you were completing risk calculations based upon the same exposure information. Again this leads to my above concern that there is a need for more clarity in presentation of the risk assessments for the community. The largest uncertainties were associated with the form and the size of the fibers being used as the basis for the inherent toxicity of the particles

The text is objective in its view of the methods, but leaves the reader without an anchor to begin understanding the reasons for using all these methods.

[Comments from Reviewer #3]:

The text seems to treat the various methods objectively, but I feel that there could be more discussion in the background section regarding why there are so many models being used, and some of the complexities, and current work being done to try to clarify the "holes" in the existing data. For example, Pg 24 states that the historical epidemiological studies "have a great deal of uncertainty associated with them", but the reasons for those uncertainties are barely discussed. While the fact that exposure to asbestos causes disease is well known to the public, the discussions on how different size and shape fibers may contribute to diseases is not well known, and can be quite confusing. A brief discussion at the beginning of the "Defining 'Asbestos'" portion on Pg 9 would be useful to help clarify the data that follows. That could include the different ways that different analysis methods count "fibers", "structures" or "particles" and how refinements of both sampling and analysis techniques have influenced the evolving information about how potency may be related to fiber size and shape. How both sampling and analysis techniques as well as latency affects interpretations of exposure data and potential health effects could use additional discussion. Discussions of the limitations and differences between impinger data, PCM, TEM, and ISO and uncertainties about older worker exposure data versus epidemiological data and how new analysis techniques are being used to re-analyze older archived filters in an attempt to correlate past exposures, fiber size distributions and mortality could help the public understand why all of these different models are being examined. While the data about differences between analysis methods is presented, short summary statements (such as "TEM analysis can distinguish much smaller fibers and counts fibers about 1/10th the size of what are counted by PCM", or "the ISO 10312 method tries to bridge the limits of other analysis methods and provides multiple results related to fiber size, length and slenderness ratios"), can help to clarify why there are controversies regarding fiber-size specific risks.

Discussion of fiber morphology differences and past exposure data and epidemiological data from mining versus other asbestos trades, and a comparison with the fiber morphology from the NOA at El Dorado could help the public understand how their potential exposures compare to that of "classic" asbestos exposures, as well as NOA exposures in different locations around the world.

Perhaps the "Summary – Asbestos Risk Methods" on page 18 could be moved to the beginning of the section, as a kind of preamble.

Q#2 – Response from ATSDR: *The peer reviewers' comments made clear to us that we needed to expand the basic explanation of risk and what it means. We added an expanded and simplified discussion of general concepts of risk on page 14, before the introduction of risk assessment methods.*

We have also added additional explanation of why ATSDR applied different risk assessment methods to the same exposure data on pages 17 and 22. All asbestos risk methods have been *questioned and criticized, and we wanted to see the range of risks that were predicted with various methods, each of which have their strengths and weaknesses. Each risk method may have different dimensional definitions for a fiber that counts towards exposure and that is why different numerical concentrations can come from the same exposure data.*

Some suggestions by the reviewers, such as comparing fiber morphology differences between different types of exposure, are impossible. There are simply not enough data available to describe the fiber morphology and size distributions of historical worker exposures, epidemiological studies, and environmental exposures in other locations around the world. We have discussed this limitation in the document on page 12.

3. Does the health consultation clearly and adequately describe the uncertainties associated with estimating community exposures and applying any type of risk assessment method to determine risk of disease?

[Comments from Reviewer #1]:

Yes.

[Comments from Reviewer #2]:

Marginally. The Limitations are not stated in clear language, and should be for the community. One major point is that that all the risk calculations only provide estimates of the lifetime population risk. Further, I do not see where the values obtained from the risk calculations are much different from method to method. Considering the overall uncertainty of each risk assessment method used by the ATSDR, the coherence in the results needs further discussion and emphasis.

[Comments from Reviewer #3]:

In general I feel that the uncertainties involved in estimating community exposures were well explained. A statement such as "just as not every smoker develops lung cancer, not everyone who is exposed to asbestos will have the same likelihood of developing an asbestos related disease" could help the public understand that there are also uncertainties in individual responses to exposure to NOA.

I felt that the section on Risk could have used a brief discussion of the basics about risk statistics, such as what a risk of 0.004 out of 10,000 means, and how to convert that data to whole numbers. Also, the Death Rates per 100,000 in Table 5 *[Data revised and table renamed Table 1 in revised report]* are not directly comparable to the risks in Table 3 *[Table 4 in revised report]*.

I feel it would be useful to include mortality rates for smoking (1 pack, 3 packs) a day in Table 5 *[Data revised and table renamed Table 1 in revised report]*.

Q#3 – Response from ATSDR: *We discuss uncertainties of the various risk methods beginning on page 29. In agreement with reviewer #2, we were also surprised to find that the predicted risks were not vastly different between risk methods using such different assumptions. We hypothesize that this result might reflect the large uncertainties present in the historical epidemiological data upon which all the risk methods are ultimately based.*

To improve our explanation of risk, we added an expanded and simplified discussion of the purpose and meaning of risk assessment immediately before the introduction of risk assessment methods.

The mortality data used to create the former Table 5 did not contain deaths due to smoking, but merely reported the immediate cause of death (e.g., lung cancer, vehicular accident, etc.) Smoking is known to be a cause or contributing factor in many different diseases, including several types of cancer, heart disease, aneurysms, bronchitis, emphysema, and stroke. While we have seen unreferenced statements that smoking may be associated with a lifetime risk of dying of a smoking-related disease of 1 in 2, or 0.5, finding the original data and references and confirming these statements are beyond the scope of this health consultation.

Because the annual mortality rates in the original Table 5 were difficult to compare with risk estimates, we changed the focus of the table to lifetime risks for various occurrences and used different data sources. We moved the table up to the general risk section added in response to reviewer comments and it became Table 1.

4. In addition to the evaluation of EPA activity-based sampling data, the health consultation presents a discussion of additional investigations/findings related to asbestos in the El Dorado Hills area. Does this discussion improve confidence in conclusions that would otherwise be based solely on theoretical risk assessment?

[Comments from Reviewer #1]:

Yes.

[Comments from Reviewer #2]:

From the point of view of a community member. No. The language is very unclear. I understand because of my background and training. Further, does the community really need to know the details of the aspect ratios and other assumptions used by each method? These would be better presented in an appendix.

The data from other locations seems irrelevant in light of the fact that you have collected all the local data. It is unfortunate that you have spent more time on this aspect of the analysis rather than dealing effectively with other activity scenarios, and providing estimates of uncertainty caused by not completing other sampling scenarios outlined by the community.

[Comments from Reviewer #3]:

Inclusion of data from other sources and investigations does improve confidence, as otherwise the public may feel that other data is being suppressed or ignored. The variability of the range of potential exposures may provide a good opportunity to emphasize that simple precautions to keep down dust generation, such as wetting, may allow a hundred or thousand fold reduction in airborne concentrations. This may encourage citizens to take such precautions, and encourages awareness that their personal actions do have a large effect on their potential exposure to asbestos.

Q#4 – Response from ATSDR: *Thank you for your comments. We had heard that some felt the activity based sampling may not be completely representative of exposures throughout El Dorado Hills, so we felt that including findings from all the studies done in and around El Dorado Hills would build confidence, especially since the findings were generally consistent. We have added additional language explaining the purpose of including this data on page 35.*

Yes, we feel the community member does really need to know at least some of the details of aspect ratios and assumptions of the various risk methods, if they want to critically judge some of the statements that have been made in the community. For example, although the Berman and Crump risk method assigns a much greater potency to amphibole fibers than the IRIS method, only a tiny fraction of the fibers counted by the IRIS method are long and thin enough to count in the Berman and Crump method—so that, in this case, the predicted risk is not very different.

5. Does the discussion of other naturally occurring asbestos sites/areas in the United States provide an adequate basis for comparing public health responses in similar situations?

[Comments from Reviewer #1]:

No. It helps, but only partially. Public health responses are so dependent on fiber type, fiber length, and variations in exposure based on lifestyle activities and air exchange rates that extrapolations to other sites/areas would be highly uncertain.

[Comments from Reviewer #2]:

No, it just provides more information. Each situation is different, what should be paramount is a presentation that focuses critically on the situation at hand.

What is surprising is the lack of a question on the exposure assessment. In contrast to many previous studies of this type there were actual activity based sampling and analyses. This is an important set of data, and has far more relevance than comparisons with other locations. What disappoints me is that the idea had to come at the request of the community member, kudos to Him or Her; and not from the ATSDR. The data are an excellent example of what should be done at all waste site health investigations, and should be a more prominent part of the conclusions as to why a health study is not necessary.

Further, there are some legitimate concerns about some of the scenarios. The most obvious is the limited amount of time toddlers and children less than 5 years of age spend in dirt. So children just play in the dirt and dig. The “activities” concerns of the community should be revisited once more by the ATSDR before the report is issued.

This study is actually a model of the types of exposure data that should be routinely collected in health consultations. It would reduce uncertainties and give more strength to conclusion.

[Comments from Reviewer #3]:

The 2/3 of a page of discussion on Pg 33 about what the actual public health responses have been in other communities could have been expanded, as there were little details provided. The range of potential exposures found during activity based sampling have a similar range to those found in El Dorado County, but the responses are varied. Further discussion could help explain why there were different responses or no responses given for some sites.

Q#5 – Response from ATSDR: *Thank you for your comments. We have added additional discussion of why we added this section on other NOA sites on page 40. This was done to respond to several community concerns that El Dorado Hills was being "singled out"; various community members and stakeholders requested ATSDR to compare what happened at El Dorado Hills with other NOA sites in California and the U.S. We agree that the responses taken at NOA sites will always be site-specific, but learning about experiences and actions taken at other sites helps provide context for the community.*

6. Are the conclusions and recommendations appropriate in view of the potential community asbestos exposures as described in the health consultation?

[Comments from Reviewer #1]:

Yes. The many uncertainties resulting from the quite sparse databases that are relied upon are appropriately caveated, and the conclusions drawn, and the recommendations made are very reasonable for public health guidance.

[Comments from Reviewer #2]:

Yes the conclusions appear appropriate, but not adequately summarized in light of the extensive exposure data. For example if some manager just read the conclusion about the lack of a need for a health study, he or she: 1. would have no idea that the risk assessment is based upon actual exposure sampling data (using activity based sampling), and 2. The number of projected people that may contract asbestos related disease based upon a population of 35,000 (across a wide age range) using range of risk (from all estimation procedures) calculated for the local situation. All of the information is vaguely presented, and considering the good ideas provided to improve the exposure assessment the community be provided a more quantitative summary supporting the ultimate conclusions. I would still agree with the conclusions.

[Comments from Reviewer #3]:

Yes, based on the range of exposures found, the relatively new age of the community, population mobility, and the lack of epidemiological data showing otherwise, the conclusions and recommendations appear to be appropriate. The indications that air monitoring and epidemiological studies will continue, as well as proposed informational campaigns, is important, and should provide further opportunities for community outreach and lessening of potential exposures.

Q#6 – Response from ATSDR: *Thank you for your comments. We have included additional text in the conclusions summary to emphasize that the risk calculations used site specific, activity-based sampling from El Dorado Hills. However, our risk results do not support any prediction of the actual number of people who might become sick from exposure in this community because of the wide range of predicted risks and the uncertainties associated with the risk methods used. We hope that the additional discussion of risk that was added in response to prior comments will help clarify that our intention in calculating theoretical risk was only to gain a general idea of potential risk ranges to direct us towards reasonable public health responses.*

7. Are there any other comments about the health consultation that you would like to make?

[Comments from Reviewer #1]:

I commend the authors for the preparation of this quite thorough and informative review, and for coming up with very reasonable conclusions and recommendations. I also want to commend ATSDR for going well beyond normal health agency practice in commissioning the additional TEM analyses of the EPA personal sampling filters. This added a new dimension to the validity of the risk assessment.

[Comments from Reviewer #2]:

None

[Comments from Reviewer #3]:

Hopefully, taking appropriate dust control measures will be incorporated into various municipal policies, but probably equally important will be having the public turn those same dust control measures into nearly unconscious habits. Greater emphasis could be placed on opportunities for education about the fact that the differences between a high exposure to asbestos and a low or negligible exposure will not be perceptible, and that it is through individual personal habit changes that people can influence their own future health. There is a balance that needs to be found, so that the public sees this kind of information as empowering themselves to make healthy changes, rather than being seen as "the Government" attempting to shift responsibility, and saying people's health is entirely influenced by their own choices.

Q#7 – Response from ATSDR: *Thank you for your comments. These points will be important for environmental and health agencies to consider as they respond to an increasing number of concerns about NOA issues.*

ADDITIONAL QUESTIONS:

A1. Are there any comments on ATSDR's peer review process?

[Comments from Reviewer #1]:

It is well considered and appropriate.

[Comments from Reviewer #2]:

None

[Comments from Reviewer #3]:

I appreciate the opportunity to contribute to this important discussion and process.

Q#A1 – Response from ATSDR: *Thank you for your comments.*

A2. Are there any other comments?

[Comments from Reviewer #1]:

No.

[Comments from Reviewer #2]:

None

[Comments from Reviewer #3]:

I would suggest not using scientific notation where possible. It was mostly well done in the main body of the consultation, but less so in the Appendices. For example, the fiber concentration data given in Tables F1, and F2 in Appendix F could easily be changed to decimal notation, and be more consistent with other parts of the consultation.

The lists of "What can you do to reduce your exposure to asbestos" found in the Fact Sheets in Appendix G, are important, and should be repeated in the consultation. Those lists could also be augmented, as there are slight differences between the ATSDR fact sheet for Workers, vs. Residents, and between those fact sheets and the Washington State Department of Health fact sheet for the Sumas River. I'd suggest including discussions about not using leaf blowers, bathing pets, keeping car windows closed, keeping dirt and dust out of cars, and potentially installing HEPA filtration in air conditioning units in these recommendations.

Q#A2 – Response from ATSDR: *Thank you for your comments. We have changed the Table notation to decimal notation (note that Table and Figure numbers have changed from the peer review draft to the final draft). In addition, we have summarized recommendations for minimizing exposures to NOA in the body of the consultation in Figure 5.*

Appendix B. Assumptions and Sources for Asbestos Exposure Estimates in Figures 4 and 6

Estimated Worker Exposure Levels

- High Levels Before Dust Control — Value: 100 f/cc
- Typical Exposure 1960s and early 1970s — Value: 10 f/cc

Sources/ Assumptions:

- Armstrong *et al.*[1] reported that at the Wittenoom mine in Australia, particle measurements collected from 1948-1958 “frequently exceeded” 1,000 particles per cubic centimeter, and that the mill was often shut down prior to testing, which would presumably lower the measured concentrations. [ATSDR used factors of 1 ppcc per 0.028 mppcf and 1 mppcf per 3 f/cc to convert 1,000 ppcc to approximately 84 f/cc.] Armstrong *et al.*[1] also reported results from a 1966 study of a new mill at Wittenoom in which the highest area (the bagging area) exibited 100 fibers longer than 5 μm per cc.
- Dement *et al*[2]. reported industrial hygiene data collected between 1930-1940 in a South Carolina textile mill using mainly chrysotile asbestos. Averages ranged from around 10-78 f/cc with upper confidence intervals as high as 117 f/cc. High values were reduced down to about 20 as process controls were instituted in the late 1960s and 1970s.
- The National Asbesotos Exposure Review Summary Report[3] presented aggregated personal and area sampling data for 17 exfoliation sites during 1972–1992. Measured PCM fiber levels inside the exfoliation facilities ranged from below detection levels to 139 f/cc. Before 1980, measured PCM fiber levels were typically in the range of 1 f/cc to 10 f/cc.

Occupational Limits[4]

- 1971 OSHA Permissible Exposure Limit — Value: 12 f/cc
- Present OSHA 30-Minute Excursion Limit — Value: 1 f/cc
- 1994-present OSHA Permissible Exposure Limit — Value: 0.1 f/cc

“Environmental” Exposure Levels

- During cleaning of house covered with with asbestos material — Value: 1.8 f/cc
- Inside house covered with with asbestos material — Value: 0.04 f/cc
- During cleaning of houses without asbestos whitewash — Value: 0.004 f/cc
- Background in village containing asbestos-covered houses — Value: 0.0004 f/cc

Sources/ Assumptions:

[1] Armstrong BK, De Klerk NH, Musk AW, Hobbs MST. Mortality in miners and millers of crocidolite in Western Australia. Br J Ind Med 1988; 45:5-13.
[2] Dement JM, Harris RL, Symons MJ, Shy CM. Exposures and mortality among chrysotile asbestos workers. Part I: exposure estimates. Am J Ind Med 1983;4:399-419.
[3] ATSDR. Summary report, exposure to asbestos-containing vermiculite from Libby, Montana at 28 processing sites in the United States. Atlanta: Department of Health and Human Services. October 2008.
[4] OSHA (Occupational Safety and Health Administration). 1994. Introduction to 29 CFR Parts 1910, 1915, 1926, occupational exposure to asbestos. Federal Register 1994 August 10;59:40964-41162.

- Luce *et al.*[5] measured asbestos concentrations in air for various scenarios in New Caledonian villages where local asbestos deposits were historically used for whitewash. The authors reported concentrations of fibers greater than 5 μm long as geometric mean values.

"Background" Levels[6]

• Near local sources	Value: 0.003 f/cc
• Typical urban air	Value: 0.00015 f/cc*
• Ambient outdoor air, remote from source	Value: 0.000000167 f/cc**

*Midpoint of range reported, from 0.000003 to 0.0003 f/cc
**Midpoint of range reported, from 0.00000003 to 0.0000003 f/cc

El Dorado Hills Levels[7]

• Maximum Levels Associated With Specific Scenarios	Range: 0.00008 to 0.08 f/cc.
• Estimates of annual average exposure	Range: 0.0006 to 0.0055 f/cc

[5] Luce D, Billon-Galland MA, Bugel I, Goldberg P, Salomon C., Fevotte J, Goldberg M. Assessment of environmental and domestic exposure to tremolite in New Caledonia. Arch Env Health 2004;59(2):91-100.
[6] Agency for Toxic Substances and Disease Registry. Toxicological profile for asbestos (update). Atlanta: U.S. Department of Health and Human Services; September 2001.
[7] Tables G1 and G2 of Appendix G of this document.

Appendix C. Mathematical Models of Exposure Response

Methods Based on EPA 1986

For lung cancer (LC), which is a relatively common cancer with multiple causes, it is assumed that there is a baseline risk in the absence of asbestos exposure. The risk of developing lung cancer upon exposure to asbestos is assumed to be proportional to the cumulative asbestos exposure (intensity of exposure times duration) and the underlying baseline risk. To account for the observed latency period, the exposures are assumed to have no effect on risk until a lag period of ten years has passed. Mathematically, this is expressed as:

$$\text{LC risk with asbestos exposure} = \text{LC baseline risk with no exposure} \times [1 + K_L \times CE10],$$

$$\text{Excess LC risk with asbestos exposure} = \text{LC baseline risk with no exposure} \times [K_L \times CE10],$$

Where K_L is the lung cancer potency factor and CE10 is the cumulative exposure (expressed in units of concentration-years) lagged by 10 years.

For mesothelioma, it is assumed that the incidence is zero in the absence of asbestos exposure. In the presence of asbestos exposure, risk increases as a nonlinear function of the exposure concentration, the duration of exposure, and the time since first exposure, as follows:

$$\text{Mesothelioma risk} = 3 \times K_M \times \int_0^{t-10} E(u) \times (t - u - 10)^2 \, du,$$

Where K_M is the mesothelioma potency factor, E(u) is the exposure as a function of time, t is the time from onset of exposure, and u represents incremental time units over the duration of exposure (the coefficient 3 is included to simplify the integrated equation). When E(u) is constant (E_c) over an exposure duration d, this integral can be solved to obtain the following:

Mesothelioma risk	$= 0$	$0 < t < 10$
	$= K_M \times E_c \times (t - 10)^3$	$10 < t < 10 + d$
	$= K_M \times E_c \times (t - 10)^3 - (t - 10 - d)^3$	$t > d + 10$

In this consultation, changing exposures throughout life were addressed with the above equation by calculating risk separately for each year's average, continuous exposure and summing the total risk.

Hodgson and Darnton Method, 2000

The Hodgson and Darnton model is based upon an examination of 17 asbestos exposed cohorts for which exposure data exist. Three of the cohorts have been split into 2 sub-cohorts as the original study showed differing exposures or outcomes based upon fiber type or sex. The study focus on developing risk models for the three most prevalent asbestos minerals in commercial use, chrysotile, amosite, and crocidolite. For mesothelioma risk estimates of the various minerals, crocidolite, amosite, and chrysotile were shown to vary on the order of 0.5, 0.1 and 0.001 (% per fiber/ml-year). The results for lung cancer were complicated by the large differences seen in the Quebec and Carolina cohorts and ranged from 0.03 to 6.7 (% per fiber/ml-year). The amphibole data are more consistent with mean risk for all amphibole cohorts of 4.8% per f/ml-yr.

The Hodgson and Darnton method deviates significantly from the other methods presented here in that the other methods use the cautious default assumption that risk is proportional to dose. Hodgson and Darnton suggest that the present data support a non-linear exposure response. However, they conclude that only peritoneal mesothelioma can be statistically shown to be non-linear, and a linear relationship remains arguable for pleural and lung tumors.

Hodgson and Darnton suggest the following model best predicts the non-linear relationship of asbestos exposures to combined pleural and peritoneal mesothelioma,

$$P_{\mathrm{M}} = A_{\mathrm{pl}}X^{r} + A_{\mathrm{pr}}X^{t}$$

> where P_{M} is the percent excess mortality, r and t are the pleural and peritoneal slopes of the exposure response on a log–log scale, A_{pl} and A_{pr} are constants of proportionality for the pleural and peritoneal elements of the risk respectively, and X is cumulative exposure in f/ml-yr.

Using the best estimates for the model parameters P_{M} can be calculated for the various minerals using the following table.

Slope/Fibre	*Apl*	95% Confidence Interval	*Apr*	95% CI
Best estimate slope (r=0.75, t=2.1)				
Crocidolite	**0.94a**	(0.71,1.2)	0.0022	(0.0011,0.0039)
Amosite	**0.13b**	(0.060,0.25)	0.0006	(0.00025,0.0012)
Chrysotile	**0.0047a**	(0.0030,0.0069)		

The model for non-linear lung cancer is;

$$P_{\mathrm{L}} = A_{\mathrm{L}}X^{r}$$

Best estimates of lung cancer model parameters yield the following,

Fiber/model	AL	95% CI
Amphibole		
Best (r=1.3)	1.6	(1.2, 1.9)
Chrysotile		
Best (r=1.3)	0.028	

The Hodgson and Darnton method offers a unique look at risk from asbestos exposure because it departs from the risk models used in almost all other risk assessment methods [58,34,60,62,63]. It also includes some important studies (South Africa) not used in other methods. However, it should be pointed out that the calculated P_M assumes exposure begins at age 30 for a duration of 5 years and absolute mortality is calculated for ages 40 – 80 (10 year latency). The method currently does not address early life exposures (although a correction can be made for exposure starting as low as 20 years of age), nor does it address very long exposures. Consecutive 5 year periods can be added together to get a total risk but due to life-table differences this total risk is not completely accurate. In addition, as in all the methods presented in this document, the predictions for community exposure in El Dorado Hills are made for exposure levels well below the range of those observed in the occupational studies evaluated in the method.

Appendix D. Life Table Analysis

Many of the risk calculations performed in this health consultation were based on "life table analysis," a method to account for discontinuous exposures and age in estimating risk of developing asbestos-related disease. Specifically, the additional risk of lung cancer (LC) and the risk of mesothelioma (meso) are addressed with this analysis. The "life table analysis" procedure used in this health consultation was developed in accord with the methods and techniques reported by Nicholson and Berman and Crump [58,60].

The following evaluation focuses on the difference in risks for "exposed" and "unexposed" groups. For the purposes of this consultation, we specify that we are only considering the specific exposure measured in El Dorado Hills activity-based and reference sampling. That is, "exposed" refers to groups who experience the exposure scenarios modeled in this consultation throughout life in this community. "Unexposed" refers to the general population who does not experience this additional exposure. It is understood that the "unexposed" population may be exposed to asbestos in other ways, such as from asbestos-containing materials in residences or workplaces, occupational exposure, etc. However, the number of cases of cancer due to these other sources of asbestos exposure is expected to be a small fraction of the total cases, so no adjustment is made in this assessment.

Lung Cancer Excess Risk Equations

Given survival of a person up to any year *i*, the excess risk (ER) of dying from LC from asbestos exposure in year *i* equals the total risk of dying from LC during year *i* under a particular asbestos exposure minus the baseline risk of dying of LC in year *i* without that asbestos exposure:

$$ER_{LC,i} = R_{LC,exp,i} - R_{LC,unexp,i} \qquad \text{(D1)}$$

Risk of Lung Cancer Mortality in the Unexposed (Baseline) Population

We first consider the baseline risk term, $R_{LC,unexp,i}$. In any year *i* this term equals the probability of surviving up to year *i* multiplied by the probability of dying from LC during year *i*. The probability of dying of LC during year *i* is the ratio of LC to all-cause death rates (DR) for year *i* multiplied by the probability of dying during year *i* (expressed here as 1 minus the probability of surviving year *i*):

$$R_{LC,unexp,i} = P_{unexp}(\text{entering year } i \text{ alive}) \times P_{unexp}(\text{dying of LC during year } i)$$

$$= P_{unexp}(\text{entering year } i \text{ alive}) \times \frac{DR_{LC,\text{unexp},i}}{DR_{all-cause,\text{unexp},i}} \times (1 - P_{unexp}(\text{surviving year } i)) \qquad \text{(D2)}$$

Assuming the death rate in a population is approximately constant over a short time interval such as one year, survival probabilities are described by an exponential function [96]. The number of people surviving to the end of the year (N_{i+1}) is computed from the number of people alive at the start of the year (N_i) as follows:

$$N_{i+1} = N_i \times exp(-DR_i)$$

Thus, given survival up to the start of year i, the probability of surviving year i alive (N_{i+1} / N_i) is given by:

$$P_{unexp}(\text{surviving year } i) = exp(- DR_{all\text{-}cause,\text{unexp},i}) \qquad \text{(D3)}$$

The probability of entering year *i* alive is the product of surviving each of the preceding years:

$$= \prod_{j=1}^{i-1} P_{unexp}(\text{surviving year } j),$$

$$= \prod_{j=1}^{i-1} exp(- DR_{all\text{-}cause,\text{unexp},j}) \qquad \text{(D4)}$$

Substituting, the equation for unexposed lung cancer risk of dying in year *i* can be written:

$$R_{LC,\text{unexp},i} = \frac{DR_{LC,\text{unexp},i}}{DR_{all-cause,\text{unexp},i}} \times (1 - exp(- DR_{all\text{-}cause,\text{unexp},i})) \times \prod_{j=1}^{i-1} exp(- DR_{all\text{-}cause,\text{unexp},j}) \quad \text{(D5)}$$

Lung cancer death rates for the general population (assumed to be mostly unexposed) are available for years up to 2003 from the National Center for Health Statistics (NCHS) [75]. The information is given in 5-year age blocks in units of deaths per 100,000. Thus, the death rates must be divided by 100,000 to put them in fractional form before use in the exponent term above. The NCHS also provides life tables from which all-cause death rates can be calculated using equation D3 above [76].

Risk of Lung Cancer in the Population Exposed to Asbestos
A parallel procedure is used to determine the total exposed risk term, $R_{LC,\text{exp},i}$.

$$R_{LC,\text{exp},i} = \frac{DR_{LC,\text{exp},i}}{DR_{all-cause,\text{exp},i}} \times P_{exp}(\text{entering year } i \text{ alive}) \times (1 - P_{exp}(\text{surviving year } i)) \quad \text{(D6)}$$

The death rate from lung cancer in the exposed population in year *i* is calculated as described in Appendix C, as follows:

$$DR_{LC,\text{exp},i} = DR_{LC,\text{unexp},i} \times (1+CE10_i \times K_L), \qquad \text{(D7)}$$

where $CE10_i$ is the cumulative exposure lagged by 10 years and K_L is the lung cancer potency factor.

The all-cause death rate in the exposed population in year *i* is computed as:

$$DR_{all\text{-}cause,\text{exp},i} = DR_{all\text{-}cause,\text{unexp},i} - DR_{LC,\text{unexp},i} + DR_{LC,\text{exp},i} + DR_{meso,\text{exp},i}$$

$$= DR_{all\text{-}cause,\mathrm{unexp},i} + (DR_{LC,\mathrm{unexp},i} \times \mathrm{CE10}_i \times \mathrm{K_L}) + \mathrm{m}_i, \qquad \text{(D8)}$$

where m_i is the incidence of mesothelioma in the exposed population in year ***i***, calculated as described in Appendix C.

The probability terms are similar to the unexposed cases except they use the exposed death rate terms.

$$\mathrm{P_{exp}}(\text{surviving year } i) = exp(- DR_{all\text{-}cause,\mathrm{exp},i}) \qquad \text{(D9)}$$

$$\mathrm{P_{exp}}(\text{entering year } i \text{ alive}) = \prod_{j=1}^{i-1} exp(- DR_{all\text{-}cause,\mathrm{exp},j}) \qquad \text{(D10)}$$

Therefore, the equation for the risk of dying from lung cancer in year ***i*** in the asbestos-exposed population can be written:

$$\mathrm{R}_{\mathrm{LC,exp},i} =$$

$$\frac{DR_{LC,\mathrm{unexp},i} \times (1 + \mathrm{CE10}_i \times \mathrm{K_L})}{DR_{all-cause,\mathrm{unexp},i} + (DR_{LC,\mathrm{unexp},i} \times \mathrm{CE10}_i \times \mathrm{K_L}) + \mathrm{m}_i} \times$$

$$\{1 - exp[-(DR_{all\text{-}cause,\mathrm{unexp},i} + (DR_{LC,\mathrm{unexp},i} \times \mathrm{CE10_i} \times \mathrm{K_L}) + \mathrm{m}_i)]\} \times$$

$$\prod_{j=1}^{i-1} \{ exp[-(DR_{all\text{-}cause,\mathrm{unexp},j} + (DR_{LC,\mathrm{unexp},j} \times \mathrm{CE10_i} \times \mathrm{K_L}) + \mathrm{m}_j)]\} \qquad \text{(D11)}$$

Mesothelioma Risk Equations

The death rate from mesothelioma in people who are not exposed to asbestos is very low and is generally assumed to be zero. Under asbestos exposure, the risk of dying of mesothelioma in year ***i*** is given by a similar equation as for the LC case:

$$\mathrm{R}_{\mathrm{meso,exp},i} = \mathrm{P_{exp}}(\text{entering year } i \text{ alive}) \times \mathrm{P_{exp}}(\text{dying of meso during year } i)$$

$$= \mathrm{P_{exp}}(\text{entering year } i \text{ alive}) \times \frac{DR_{meso,\mathrm{exp},i}}{DR_{all-cause,\mathrm{exp},i}} \times (1 - \mathrm{P_{exp}}(\text{surviving year } i))$$

Substituting in from equation C8 to C10 yields:

$$\mathrm{R}_{\mathrm{meso,exp},i} = \prod_{j=1}^{i-1} exp(- DR_{all\text{-}cause,\mathrm{exp},j}) \times \frac{\mathrm{m}(i)}{DR_{all-cause,\mathrm{unexp},i} + (DR_{LC,\mathrm{unexp},i} \times \mathrm{CE10}_i \times \mathrm{K_L}) + \mathrm{m}_i}$$

$$\times \{1 - exp(-[DR_{all\text{-}cause,\mathrm{unexp},i} + (DR_{LC,\mathrm{unexp},i} \times \mathrm{CE10_i} \times \mathrm{K_L}) + \mathrm{m}_i])\},$$

where m_i is the mesothelioma risk expression from Appendix C, which for constant periods of exposure E_c of duration d evaluated at time t from onset of exposure is given by:

m_i	$= 0$	$0 < t < 10$
	$= K_M \times E_c \times (t - 10)^3$	$10 < t < 10 + d$
	$= K_M \times E_c \times (t - 10)^3 - (t - 10 - d)^3$	$t > d + 10$

Estimates of Risk from Life Table Analysis

ATSDR developed an Excel spreadsheet to estimate risks from lung cancer and mesothelioma using the equations described above, for the exposure assumptions developed for El Dorado Hills. The exposure assumptions included a lifetime of exposure, starting at birth, to asbestos at levels estimated from activity-based sampling in the community, as described in the body of the document. Mortality tables were obtained for 2003 from the National Center for Health Statistics [75,76]. Lifetime risk was estimated by summing yearly risks until no survivors remained, age 120 for the 2003 data. Because risk is dependent on the number of people surviving, later years contributed only a small amount to lifetime risk. The steps followed in the life table analysis are:

- First, the exposure assumptions are chosen. ATSDR worked with local, state and federal stakeholders to develop appropriate exposure assumptions for El Dorado Hills, spanning low to high activity levels in age-specific categories of exposure over a resident's lifetime.

- Next, a risk method is chosen. This selection sets the structure size and mineralogy definitions to use to determine exposure levels from activity based sampling; it also sets the appropriate potency factors developed for that structure definition.

- For each year of life, the average exposure concentration (in the appropriate units corresponding to the structure definition of interest) is calculated, then combined with mortality data and appropriate risk method potencies to calculate risks of lung cancer and mesothelioma, as well as survival functions for use in future years' calculations. The risks for all years are summed to obtain the total risk.

For mesothelioma, calculations for changing exposure levels were simplified by performing separate calculations for each constant-level period; risks were then summed to obtain the total mesothelioma risk for all exposures.

Appendix E. ATSDR Additional Analysis of El Dorado Hills Data

Background

The U.S. Environmental Protection Agency (EPA) collected activity-based samples in El Dorado Hills, California, locations in Fall 2004 as part of its multimedia exposure assessment. This occurred at about the same time the Agency for Toxic Substances and Disease Registry (ATSDR) was evaluating naturally occurring asbestos (NOA) exposures at Oak Ridge High School in El Dorado Hills. ATSDR released its health consultation on Oak Ridge High School for public comment at the same time EPA released results of the activity-based sampling, in May 2005. In the final version of the Oak Ridge High School health consultation, released in January 2006, ATSDR committed to evaluating the EPA activity-based sampling data in an effort to make a determination of the public health impact of NOA exposures in the general community.

Goals and Findings of EPA Analysis of Activity-Based Samples

EPA described the objectives and analysis procedures of the activity-based sampling in its Quality Assurance Project Plan finalized in September 2004 [E1]. EPA's analysis of the samples was intended to give data of sufficient quality to determine if activities were associated with elevated asbestos exposures compared to reference stations where no activities were performed [E1]. The comparison would be done using Z-test statistical methods similar to those specified in the Asbestos Hazard and Emergency Response Act (AHERA) method for comparing indoor and outdoor air measurements to assess asbestos cleanups in school buildings. Analysis of the activity-based sampling air filters was done by transmission electron microscopy. The laboratory was directed to use International Standard Organization (ISO) counting methods to reach the specified analytical sensitivity based on total asbestos structures (all regulated asbestos structures, irrespective of length, with aspect ratio greater than or equal to 3:1). Analytical sensitivity was specified as 0.001 total asbestos structures per cubic centimeter (s/cc) for samples collected using less than 4,000 liters of air and 0.0003 s/cc for samples collected using greater than 4,000 liters of air. The laboratory was further directed to stop counting before reaching the required analytical sensitivity if 50 primary structures were counted (completing counting on the grid containing the 50^{th} primary structure), provided the resulting concentration would exceed 0.1 s/cc [E1].

The results of the original analysis allowed comparison between activities and reference stations and showed that activities could result in significantly increased levels of exposure. EPA finalized the Preliminary Assessment and Site Inspection (PA/SI) report in January 2006 [E2]. EPA focused its presentation of results on PCM-equivalent structures (structures greater than or equal to 5 μm long, between 0.25 and 3 μm wide, and with aspect ratios greater than or equal to 3:1) and on total asbestos structures ("AHERA-like" total structures, structures with aspect ratios greater than or equal to 3:1, irrespective of length). PCM-equivalent structures are the size of structures specified for use in EPA's Integrated Risk Information System (IRIS) risk assessment method, typically used by the Superfund program for risk assessment, and AHERA structures are those specified for characterizing school cleanups in the AHERA program. In Table 6.1 of the final report, EPA showed that most activities were associated with statistically significant elevations of exposure compared to reference stations, for either PCM-equivalent or AHERA structures [E2].

ATSDR's Need For Additional Information

ATSDR planned to examine the activity-based sampling results and make recommendations as to the degree of public health risk from such exposures in the community. This could have been done using EPA's Integrated Risk Information System (IRIS) risk method, which can use PCM-equivalent data. However, at the time ATSDR started looking at the data, events were occurring that suggested that relying solely on the IRIS method might not be the best science for determining public health risk.

- Some stakeholders raised an issue that most of the structures detected in the EPA sampling were not true asbestos fibers, but were instead so-called "cleavage fragments" or nonasbestiform particles; use of the IRIS method would overestimate risk [E3]. The assertion was made largely on the basis that many of the structures detected were shorter or thicker than commercial asbestos fibers. (ATSDR did not necessarily agree, since there is no strong evidence indicating cleavage fragments are non-toxic and NIOSH recommends counting them. Also, no accepted method exists for differentiating between asbestiform particles and cleavage fragments of similar dimensions.)
- Local community members and activists asserted that using the IRIS method, based mainly on epidemiological studies of chrysotile asbestos workers, would not be protective. (Most of the structures detected in El Dorado Hills were amphibole, and many reports in the scientific literature have concluded that amphibole asbestos is significantly more potent in causing some types of cancer than chrysotile.)
- El Dorado County sought advice from D.W. Berman, a consultant and co-author of the Berman and Crump method for assessing asbestos risk. Dr. Berman's letters to the county indicated that use of his approach would make it unnecessary to differentiate between fibers and cleavage fragments and would be more scientifically appropriate because it counted the length of fibers found to be toxic [E4,E5].

At the time (2005-2006), the Berman and Crump risk method was considered as improving on the IRIS method for assessing asbestos inhalation risk. The Berman and Crump method was drafted in 2001 and revised in 2003 in response to a generally favorable peer consultation panel discussion [E6,E7]. It assigns different potencies to amphibole and chrysotile asbestos and considers only long, thin structures, which the authors believed to be the greatest contributors to biological activity. However, the 2003 revised method did not address some of the recommendations of the peer consultation panel, and there were lingering questions as to some of the method's assumptions – the method has never been used or adopted by EPA. ATSDR was aware of the scientific questions surrounding the Berman and Crump method. But we felt that including this method in our evaluation would generate information that would help address the issues listed in the bullets above.

At about the same time, EPA initiated further work to expand and improve the Berman and Crump method to address some of the outstanding issues. This work, led by the Office of Solid Waste and Emergency Response (OSWER), was undertaken in hopes of developing an interim risk assessment method for the Superfund program. The method was to be used until another group within EPA completed their ongoing update of the IRIS method. ATSDR reviewed preliminary drafts of this work which indicated that risk was most associated with long amphibole structures (greater than 10 μm long); structures up to 1.5 μm in diameter contributed to risk. Although ATSDR had reservations about the utility of this method similar to our reservations about the Berman and Crump method, we planned to include it as a comparison to the Berman and Crump method.

To use either the Berman and Crump method or the proposed OSWER method, we needed information on the long (greater than 10 μm long) structure concentrations in the El Dorado Hills sampling. EPA provided ATSDR with a Microsoft Access database containing the raw data from the PA/SI, including structure dimensions [E8]. ATSDR examined the greater than 10 μm long subset of structure data from the database to determine whether it could be used for the type of risk assessment we proposed. ATSDR found that the analytical sensitivity was too low for us to use the long structure data.

Analytical sensitivity is a function of the amount of air drawn through the filter when collecting an air sample and the area of the filter examined later under the electron microscope (that is determined by the "number of grids" examined by the lab). For both PCM-equivalent and AHERA-like structures, most samples had enough structures present on the filters that reliable counts could be made and the samples could be compared with one another. In contrast, relatively few long structures were present on the filters. In many cases the lab reached the stopping rule based on total structures before it had counted any long structures, so many of the samples were "nondetect" for long structures. The low number of structures counted in samples that did detect long structures resulted in large confidence intervals (uncertainty that the number of fibers counted accurately represented the number of fibers present). These two factors made it impossible to compare long structure results between samples. In addition, the analytical sensitivity/detection limits were too high for meaningful application of the long-structure risk methods described above. (Preliminary calculations showed that concentrations of long structures lower than these detection limits, but not zero, could contribute to unacceptable risk).

The analytical sensitivity could be improved by counting a greater number of grids (greater filter area) on each filter. The resulting long structure data would be more useful in evaluating risk using long-structure risk methods. To obtain this information, ATSDR's Division of Regional Operations provided funding to allow additional analysis of filters that had been retained from EPA's original analysis.

Additional Analysis and Results

To conserve limited funds, ATSDR selected 182 of the original 316 samples for additional analysis. The analysis used direct ISO methods to count structures greater than or equal to 10 μm long and less than or equal to 1.5 μm in diameter. Because few of these structures were present, we specified that the laboratory was to count until 10 of these structures were identified or until a total of 400 grids on the filter had been counted, whichever came first. This was anticipated to give sufficient sensitivity to allow meaningful application of "long" structure risk methods described above. In addition, ATSDR instructed the laboratory to perform the counting at a lower magnification (which saves analysis time). Most of the structures were not so thin as to limit visibility at the lower magnification, so this was not expected to have an impact on overall structure count. The additional analysis was performed by the same laboratory that had performed the original analysis (LabCor, Seattle, WA).

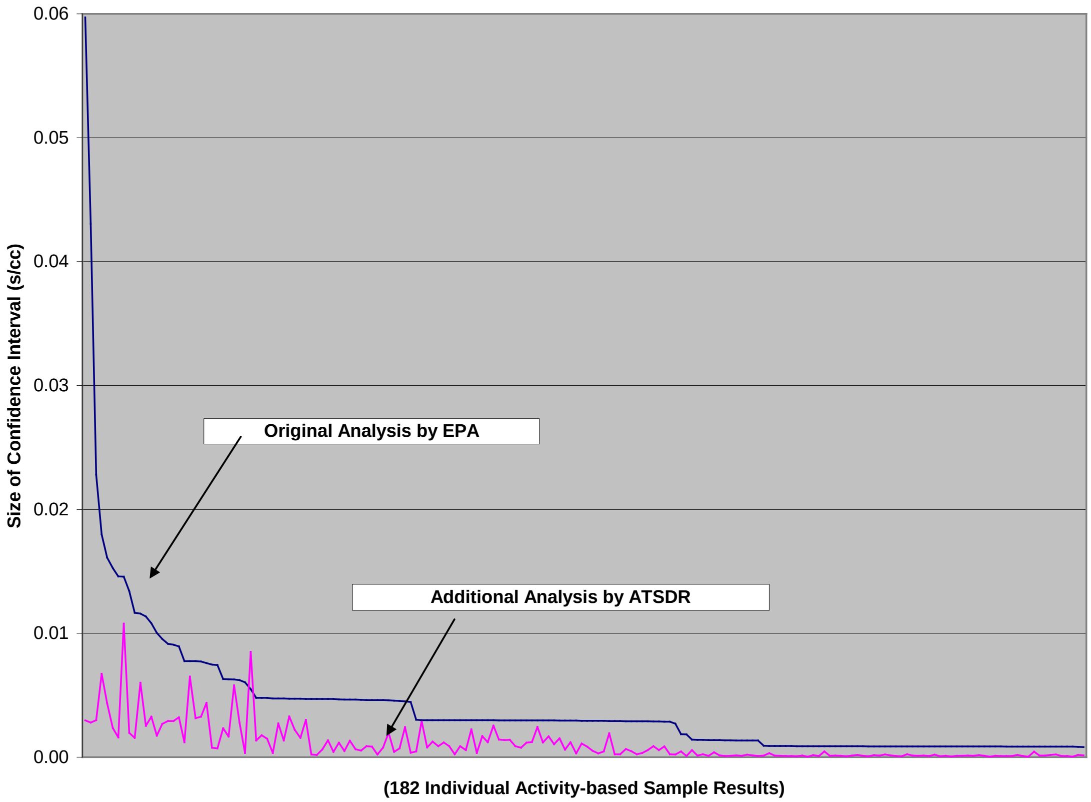
Raw data and data summaries were provided to ATSDR in September 2007 [E9]. Table E1 summarizes the improvement in structure detection that was attained with the additional analysis. The additional analysis improved the sensitivity so that long structure concentrations could be assigned to over 80% of the samples originally reported as nondetect.

Table E1. Summary of Long Structure Data*

Analysis	Total Number of Samples Analyzed	Number of Samples With Nondetect Result	Range of Detection Limits for Nondetects
EPA Original Analysis	182	113	0.0008—0.04
ATSDR Additional Analysis	182	21	0.00004—0.01
*Long structures defined as regulated asbestos structures greater than or equal to 10 μm long and less than 1.5 μm wide.			

The confidence in the detected values was also improved with the additional analysis. Figure E1 shows that the size of the confidence interval (based on Poisson distributions of structures on the air filter, per ISO method specifications) was decreased significantly for almost all the samples analyzed. This indicates a greater confidence in the laboratory results for structure concentration on the filters. (Note: Although the results in Figure E1 indicate greater confidence in the laboratory findings was achieved with the additional analysis, there are still a great many uncertainties with other aspects of the activity-based sampling and risk estimation, as described in the accompanying health consultation. We have not attempted to estimate confidence intervals for any exposure or risk estimates listed in the consultation.)

Figure E1. Improvement in Confidence in Analysis Results



Additional analysis reduced the size of the Poisson 95% confidence interval around the laboratory-reported structure concentration for structures greater than 10 μm long and less than 1.5 μm wide. The plot shows difference between upper and lower confidence limits (in structures per cubic centimeter, calculated according to ISO conventions) for each sample for the original EPA analysis of long fibers (in blue) and for the ATSDR re-analysis (in pink). The additional analysis resulted in an average 75% reduction in the size of the confidence interval, indicating greater confidence in the ATSDR long structure results. (To ease viewing, the data were sorted from the highest to lowest EPA confidence interval size. The same samples are paired in the plot; thus the ATSDR additional analysis is not sorted from high to low.)

Timing and New Developments

ATSDR identified the need for further analysis in spring/summer 2006, and over the next several months worked to obtain funding, develop appropriate counting and stopping rules with the laboratory, and identify the appropriate subset of samples to analyze. The laboratory started analyzing samples in early 2007, and ATSDR received the final report in September 2007 (because of the large number of grids counted to obtain high analytical sensitivity, each sample took about a day to analyze).

Meanwhile, EPA continued developing the OSWER proposed interim method. ATSDR provided informal comments on a Fall 2006 draft through its participation on the Technical Review Workgroup Asbestos Subcommittee, and ATSDR provided official comments on a later draft in Winter 2008. The later draft was reduced in scope from the earlier draft and mainly described a approach for determining potency factors for use in assessing risk [E10]. Because the potency factors were not published, it was impossible to use the Winter 2008 proposed approach for risk estimation. EPA convened the Asbestos committee of the Science Advisory Board panel in July 2008 to provide technical advice on the Winter 2008 proposed OSWER approach [E10]. The Committee found that while the objective of determining influence of mineral type and dimensions on cancer potencies estimated from epidemiological studies was a worthy one, the quality of the available exposure data was generally insufficient to support the proposed approach [E11]. At this time, EPA has decided not to pursue this activity further [E12].

Because the Berman and Crump method uses similar data to the proposed OSWER approach, some feel that it is scientifically inadequate for use in assessing risk. However, others continue to assert that, despite its shortcomings, it represents an improvement over currently used risk methods. The authors have continued to publish articles on this topic in the peer-reviewed literature [E13,E14]. Finally, although there are numerous subtleties and clarifications needed for accuracy, the belief that "amphibole asbestos is more toxic" has embedded itself into the awareness of general population through media stories and discussion with local activists. El Dorado Hills community members understandably want ATSDR to consider a method that accounts for amphibole toxicity. Therefore, ATSDR proceeded to consider the 2003 Berman and Crump method, with appropriate caveats, in the health consultation.

Conclusion

The additional analysis gave results that improved ATSDR's evaluation of the sampling data by allowing application of a risk method that accounts for the effects of mineral type and dimensions on toxicity. ATSDR recognizes the scientific uncertainty and limits of this method compared to traditional risk assessment methods, especially in light of EPA's SAB review. We do, however, think this method has merit when used in comparison with results of other risk assessment methods and in conjunction with other evidence about the nature of asbestos exposures at the site.

References

E1. Ecology & Environment. Quality Assurance Project Plan, Final, El Dorado Hills Naturally Occurring Asbestos Multimedia Exposure Assessment, El Dorado Hills, California, TDD No.: 09-04-01-0011. Prepared for the U.S. Environmental Protection Agency, Region 9 Superfund Technical Assessment and Response Team. September 2004.

E2. Ecology & Environment. Preliminary Assessment and Site Inspection, El Dorado Hills Naturally Occurring Asbestos Multimedia Exposure Assessment, El Dorado Hills, California, TDD No.: 09-04-01-0011. Prepared for the U.S. Environmental Protection Agency, Region 9 Superfund Technical Assessment and Response Team. January 2006.

E3. RJ Lee Group, Inc. Evaluation of EPA's analytical data from the El Dorado Hills asbestos evaluation project. Prepared for the National Stone Sand & Gravel Association. Monroeville PA): November 2005

E4. Berman DW. Letter to VL Barber, El Dorado County Office of Education RE: Finding concerning the RJ Lee report. Aeolus, Inc. Albany (CA): February 23, 2006.

E5. Berman DW. Letter to VL Barber, El Dorado County Office of Education RE: Opinion concerning the toxicity of asbestiform and non-asbestiform particles. Aeolus, Inc. Albany (CA): June 11, 2007.

E6. Berman DW, Crump KS. Final draft: technical support document for a protocol to assess asbestos-related risk. Prepared under contract to the U.S. Environmental Protection Agency. Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, October 2003. OSWER Directive # 9345.4-06.

E7. Eastern Research Group. Report on the peer consultation workshop to discuss a proposed protocol to assess asbestos-related risk. Prepared for the U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Lexington, MA: May 30, 2003. Available online at: http://www.epa.gov/oswer/riskassessment/asbestos

E8. U.S. Environmental Protection Agency. Access database containing El Dorado Hills Activity Based Sampling Results. EDD_4-13-05.Perry.050422.mdb Created April 15, 2005.

E9. LabCor. Excel Spreadsheets Containing NADES Spreadsheet Results for ATSDR Extended Analysis. Provided in September 2007.

E10. U.S. Environmental Protection Agency. Science Advisory Board (SAB) webpage for OSWER Interim Method to Assess Asbestos-Related Carcinogenic Risk Washington: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, webpage accessed October 8, 2008. Available online at: http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/f2a5dbfe31ffa9588525701a005896d3!OpenDocument&TableRow=2.0#2 .

E11. Science Advisory Board Asbestos Committee. SAB consultation on EPA's Proposed Approach for Estimation of bin-specific cancer potency factors for inhalation exposure to asbestos. Prepared for the U.S. Environmental Protection Agency. Washington, DC: November 14, 2008.

E12. Johnson, SL. Letter to A Kane, Chair, Asbestos Committee, Science Advisory Board U.S. Environmental Protection Agency, Washington: December 29, 2008.

E13. Berman DW, Crump KS. Update of potency factors for asbestos-related lung cancer and mesothelioma. Crit Rev Toxicol 2008;38(S1):1-47.

E14. Berman DW, Crump KS. A meta-analysis of asbestos-related cancer risk that addresses fiber size and mineral type. Crit Rev Toxicol 2008;38(S1):49-73.

Appendix F. Comments Received on El Dorado Exposure Assumptions

ATSDR worked with EPA and Cal-EPA's OEHHA in the development of proposed exposure assumptions for estimating risk in El Dorado County. To obtain input from the community, ATSDR provided a draft spreadsheet describing these exposure assumptions to representatives of three groups in El Dorado County: the El Dorado County Office of Education, El Dorado County Board of Supervisors, and a Community Advisory Group made up of local private citizens. The draft spreadsheet, provided in Fall 2006 and included as Figures E2-E5 at the end of this Appendix, included sheets summarizing exposure time and duration assumptions, fiber level estimation assumptions, and explanatory text. The Agency received suggestions and comments on the spreadsheet from private citizens and the El Dorado County Office of Education. ATSDR categorized the comments into various subject areas and prepared responses or made changes to the exposure assumptions. Verbatim comments and ATSDR responses/description of changes made are listed below.

Comments on Time-Duration Assumptions

Request for additional exposure scenario: **"Please conduct risk assessment for children, ages 5 through 11, playing and digging in soil on the northwest area of Silva Valley Elementary School property, immediately adjacent and northwest of portable buildings, along property boundary. The school has or had a garden area there where children conducted planting and gardening activities similar to Jackson School's activities. Children's faces were relatively close to soil during work, within a foot or two." –**private citizen

ATSDR Response. To account for potential exposures in digging scenarios, ATSDR added 1 hour per week, 32 weeks per year of a "digging scenario" for 5-11 year olds in low, medium, and high exposure categories [assumed 2 half-hour periods of gardening activity per week for non-rainy school weeks]. In addition to the described scenario, high school science students were reported to perform soil science experiments with soil collected from school grounds. ATSDR therefore added 0.5 hour per week, 3 weeks per year, of a "digging" scenario for 12-18 year olds in all exposure categories who might collect soil and perform short-term experiments in science class. The resulting time is multiplied by the fraction 4/7 to reduce the exposure, based on professional judgment that students would be unlikely to be enrolled in a science class performing the same soil experiments every year. (4 out of 7 years chosen as reasonably conservative; 3 weeks of half-hour daily experiments also chosen as a conservative assumption.) No data are available showing exposures from gardening activities at Silva Valley Elementary. One direct result for a "digging scenario" collected at Jackson Elementary was used to estimate fiber levels for all digging scenarios.

Request to reduce time assumptions for certain categories: **"The chart assumes that a "high activity" 12-18 year old athlete will engage in athletics six hours a day/seven days a week in addition to P.E. This seems excessive. The highest activity athletes are generally those engaged in high school sports. A typical member of a high school soccer team, for example, will play games on Monday and Wednesday, which last approximately two hours each, including warm up. Fifty percent of the games are played away. Practice on Tuesday, Thursday and Friday is typically two hours a day. Although it is possible, we know of no**

students who continue to practice on their own for an additional four hours after the game or after practice. On weekends the dedicated athlete will continue to train, but we don't know of any athletes that train for six hours on Saturday and six hours on Sunday. Similarly, we wonder whether the "moderate activity" assumptions of 3 hours day/ seven days a week in addition to P.E. is appropriate for someone who is just moderately active. This assumes someone engaging in sports as soon as school lets out at 3:00 p.m. until 6:00 p.m. every school day plus weekends. We wonder if this will be considered as more than just moderate activity." –El Dorado County Office of Education

ATSDR Response: ATSDR believes the draft's explanation of assumed times and durations was unclear and may have led to this commenter's misinterpreting the assumptions. The high activity 12-18 year old was assumed to spend, in addition to 34 weeks of P.E. at 3.75 hours per week, time performing activities on asphalt courts, grassy fields, or the New York Creek trail jogging or biking. The hours per week for each of these scenarios was assumed to be 14 hours, but it was assumed that not all activities would take place each week; instead each specific activity (asphalt courts, grassy fields, trail activities) was assumed to take place during a "season" of 12 weeks per year, with the three seasons corresponding roughly to the 34 weeks of fair weather activity assumed for P.E. Similar comments could be made for the moderate activity scenario, except that longer "seasons" were assumed. The overall assumptions made originally come out to an assumption of about 14 hours of additional activity per week in addition to P.E. for the high activity scenario, and about 10-12 hours of additional activity per week in addition to P.E. for the moderate activity scenario (if corrected to account for the longer "seasons" assumed).

ATSDR obtained additional information which allowed a refinement of the weeks per year assumed in various activities. On-line weather information and data collected locally by state agencies and private corporations indicated that the rainiest months include November, December, January, February, and March, and that lower levels of asbestos in air were measured during a "rainy" season of about 13 weeks [71–73]. Assuming a 45-week school year (including breaks) running from mid-August until early June, ATSDR therefore determined that the non-rainy school year (for estimating exposures during P.E., etc.) would be 32 weeks. Allowing for summer activities, each "season" for grassy field, asphalt court, and trail activities was set at 12 weeks, for a total of 36 non-rainy weeks of activity.

In response to the information provided on soccer schedules, and in an attempt to simplify the assumptions, ATSDR has modified the "seasons" of weeks per year and the assumed hours of additional activities per week for both the moderate and high activity scenarios. Both scenarios were assumed to include 12 weeks per year of activities on grassy fields, asphalt courts, and New York Creek Trail. For the 12-18 year-olds' high activity scenario, 10 hours per week was assumed for grassy fields, asphalt courts, and trail activities. This allows for 8 hours as described by the commenter plus an additional 2 hours on the weekend. ATSDR feels this change is responsive while remaining conservative. For moderate activities, in addition to changing the assumed number of weeks per year to 12 for each activity (grassy field, asphalt court, New York Creek Trail), the hours per week assumed for each of these activities has been changed to 5, half of the "high" activity level. This value is similar to recommendations made by the U.S. Surgeon General's Office that children older than 8 and adolescents engage in "at least 60 minutes of moderate intensity, continuous activity on most days, preferably daily." [74] Total hours for extracurricular activities for 5-11 year olds was the same as for 12-18 year olds, but the proportion of time spent on grassy fields or asphalt courts was increased and time on New York Creek Trail reduced, since younger children are assumed to be more likely to engage in supervised sports activities than independent exercise.

***Request to remove walking to school on New York Creek Trail:* "We also note that the moderate and high activity scenarios all involve students walking to and from school along New York Creek Trail. Most students do not use this trail to go to school. We believe one scenario should be included that would be relevant for students and other members of the community who do not use New York Creek Trail." –**El Dorado County Office of Education

ATSDR Response: Although most students may not perform this activity, it is important to include it since students who do walk may not have another option for getting to school. (The low activity scenario is one which does not include walking to school.)

Comments on Fiber Level Assumptions

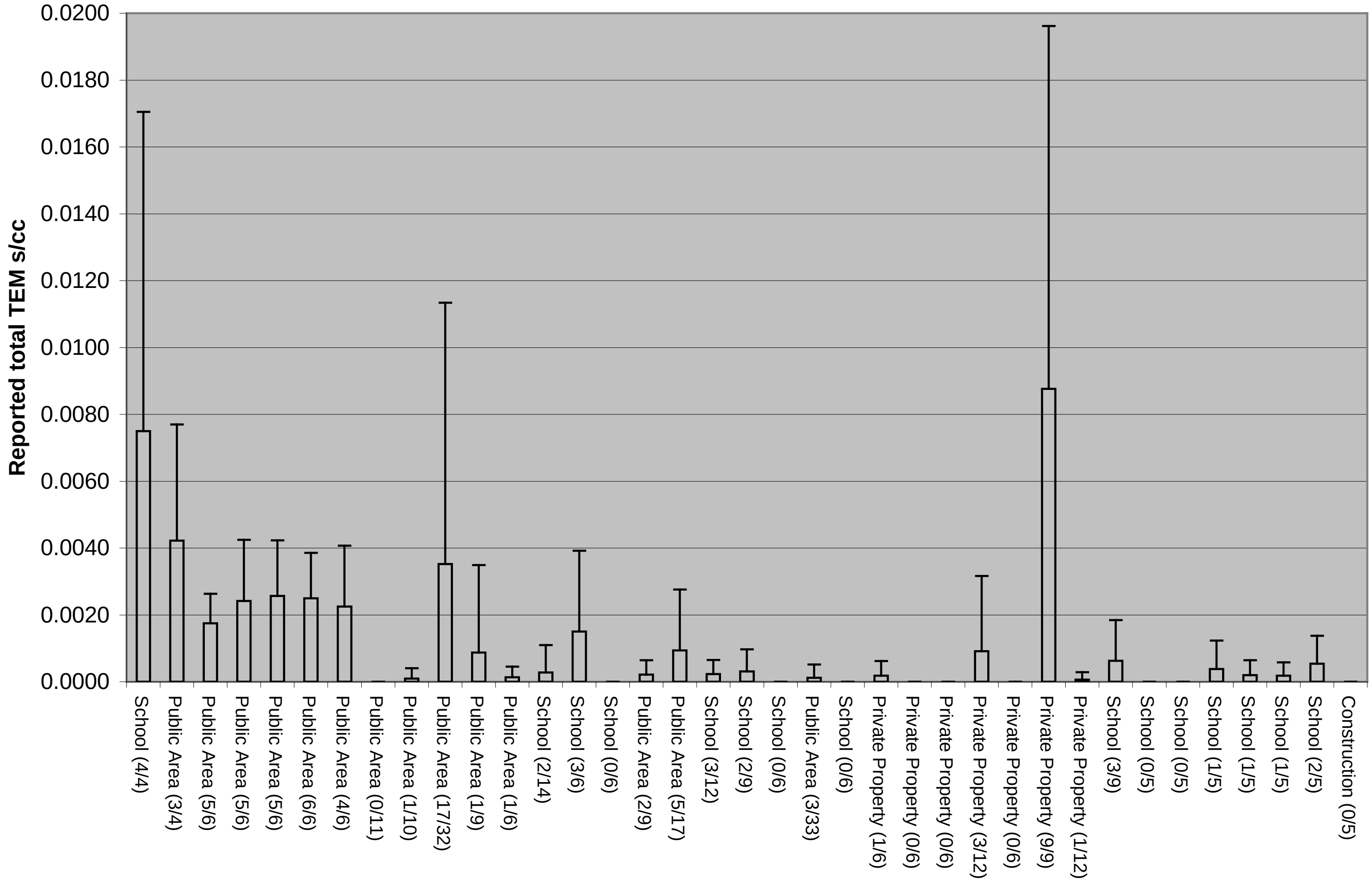
***Comments on use of background levels:* "The spreadsheet indicates that ATSDR intends to incorporate background levels in the analysis. We question whether the reference samples collected by the EPA in the study were intended to establish background levels for El Dorado Hills. We specifically asked in our response to the QAPP that the EPA include several additional sites for the stationary monitors in El Dorado Hills to provide more valid background data. DTSC also made this request. Unfortunately our requests were rejected. The number of samples and locations are not indicative of the El Dorado Hills area, do not reflect the differences in the seasons and do not reflect a 24 hour period. As you know, CARB has conducted a number of tests in the El Dorado Hills area. It may be appropriate to include their data in making assumptions of background levels." –**El Dorado County Office of Education

ATSDR Response: The EPA reference stations are the only data available which contain detailed size distribution data and therefore can be used in multiple risk models. Although CARB data was not detailed enough to use in the health consultation, ATSDR evaluated the CARB ambient monitoring to see how it might compare to the EPA reference station results. ATSDR used CARB data available on its web site [73]. The data contained a text description of each sampling location, but no details as to how the sampling was performed or exact location were available. Samples appeared to be 24-hour averages. Text descriptions stated that analysis was by transmission electron microscopy (TEM) following the AHERA method (40 CFR Part 763, Subpart E) with ARB modifications, but specific information on structure definitions, counting criteria, or changes to the standard method were not given. ATSDR assumed that the data presented on CARB's web site (both structure per cubic centimeter and fiber per cubic centimeter) represented AHERA structures greater than 0.5 μm long and with an aspect ratio greater than or equal to 5:1. For each location, ATSDR determined the average and standard deviation of all daily samples collected, counting non-detect results as zero. Figure F1 shows a summary of the results (number of detections is shown below each column) for locations in El Dorado County. The data do not include locations that were denoted as near a potential asbestos source (which were much higher), nor do they include one series of locations taken during the winter rainy season (no asbestos detected). Figure F1 indicates that other ambient monitoring locations, which included samples collected at various times from April through October, had averages ranging from non-detect to relatively high levels. The 24-hour asbestos level is quite variable, both between locations and at different sampling periods of the same location (as indicated by error bars representing standard deviation).

The mean (± standard deviation) of all CARB ambient samples in Figure F1 is 0.001±0.004 AHERA 5:1 aspect ratio s/cc. To compare, the mean of EPA activity based sampling results for all reference stations was 0.002±0.001 AHERA 3:1 aspect ratio s/cc. (The CARB value is smaller, as would be expected since 5:1 aspect ratio structures are a subset of 3:1 aspect ratio structures, but the large standard deviations show that the difference between the means is not statistically different.) *Therefore, ATSDR has determined that the EPA reference station data adequately represent background for areas away from potential sources during non-rainy periods.*

As further support, asbestos monitoring data for a local construction area were also available and are presented in the body of the document as Figures 7 and 8 [72]. This data showed levels during non-rainy periods generally similar to the CARB data, but it also included sample data from rainy periods of time. In general, the asbestos levels during the season corresponding to rainy periods (November-March) were an order of magnitude smaller than during drier periods. *Therefore, to address the fact that these data indicate significantly lower asbestos concentrations during rainy seasons, ATSDR will assume that "background" asbestos levels are one-tenth of the EPA reference station levels during a 13-week rainy period.*

Figure F1. CARB Ambient Asbestos Monitoring Summary



*NOTE: Data obtained from CARB website at http://www.arb.ca.gov/toxics/asbestos/airmon.htm in Fall 2006; further analysis performed by ATSDR in April 2008. Bars represent average structure concentration and error bars represent standard deviation.

***More comments on use of background levels:* "In addition, the use of background levels as an "additional exposure" in other risk assessment models should be discussed. If other risk models assume no exposure from background levels, even though background levels may have been present, this should be discussed. While we realize ATSDR takes a protective approach in its Consultation, we believe the value of the report will be greatly enhanced if realistic assumptions are used and any deviation from the data or methods used in generating accepted models is fully explained." –**El Dorado County Office of Education

ATSDR Response: Risk models developed from worker cohort data typically neglect background exposure. This is because the high levels of occupational exposure far outweigh any background exposures. However, it is known that lower-level exposures, such as experienced by family members living in the house of a worker or people living in the neighborhood of a processing plant, have resulted in disease. Background exposures are important to include in a place like El Dorado Hills where these "background" exposures are comparable to (and over the course of a lifetime potentially greater than) any direct activity-related exposure.

We have added discussion of this issue in the body of the document beginning on page 32. We have emphasized that the risk estimates presented in the health consultation should not be compared with results of EPA risk assessments for other sites or EPA risk ranges for Superfund cleanup.

***More comments on use of background levels:* "On the issue of using background levels in the study, we understand detectable levels of asbestos two and one-half (2.5) times higher than the background samples taken by CARB at ORHS have been measured thirteen miles out in the Pacific Ocean. http://www.asbestos.org/HealthEffects/Non-Occupational.html. According to tests completed by CARB during the period between 1998 and 2003, daily background levels in Santa Clara County were seventeen (17) times higher than the readings at ORHS even before the EPA completed their work at ORHS. Readings in Monterey County were three and one-half (3.5) times higher than the readings at ORHS. Recent readings in the Clear Creek Management Area indicate that the levels are over 100 times the readings at ORHS. We have previously provided you with this information and it is available on the CARB website. www.arb.ca.gov/toxics/asbestos/orhs.htm?PF=Y. Since there are background levels in many areas in California and the United States, the exposures in El Dorado Hills should be put in context of other areas with naturally occurring asbestos." –**El Dorado County Office of Education

ATSDR Response: ATSDR was asked to assess the risk from naturally occurring asbestos in the area around El Dorado Hills. Site specific data have been collected in El Dorado County, and the EPA activity based data is the only data for which detailed size distribution data were available. While other areas in California and elsewhere might also have naturally occurring asbestos, and therefore some potential risk, this does not affect the risk for El Dorado Hills. We have added discussion of how background contributed to risk in the document beginning on page 32, and have indicated how background in El Dorado Hills area compares to ambient levels reported in general U.S. urban environments. We also included a section describing some findings at other U.S. naturally occurring asbestos areas beginning on page 40.

Comment that activity-based sampling scenarios may not represent true exposures: **"The Asphalt Court Scenarios will use data that included the use of brooms to stir up the dust while 4-square and basketball were played. We requested the EPA include at least one test that did not use brooms during the game, but they rejected our request and all of the games included the use of brooms. If there is any data to indicate that the broom exposure scenario approximates the exposure without the use of brooms, it should be included in the report. If not, the applicability of the data to games that do not involve the use of brooms should be discussed." –**El Dorado County Office of Education

ATSDR Response: Details of the specific actions followed during each of the activity scenarios are given in EPA's final Preliminary Assessment/ Site Inspection (PA/SI) report [7]. Brooms were used on the Rolling Hills Middle School basketball court during the first 10 minutes of a 2-hour scenario, to represent cleaning of the court that might occur before a game. The basketball and paved kindergarten playground (4-square) scenarios at Jackson Elementary School did not include any use of brooms prior to activities. It is impossible to construct an activity scenario that exactly represents actual activity patterns. ATSDR has determined that the use of data including broom use is justified since pre-game cleaning could occur or because wind, leaf blowers, or traffic might raise up dust during court activities.

Request to fully describe activity-based sampling scenarios and their relation to true exposures: **"It would be helpful if a section were devoted to explain the methods used to generate the data and how this data may differ from the actual exposure to the individual. The usefulness of the report will be greatly enhanced with a comprehensive discussion of the protocol used for the generation of the data. In addition to the use of brooms during the basketball games, issues such as the use of leaf blowers in the playground tent should be explained, especially if this data is averaged in with the other data. The height of the stationary and personal monitors, many of which were set at approx 3-4 feet, should also be included in the discussion. The fact that the baseball fields were not wetted down before the tests, even though we believe it is common practice of the fields where the tests were conducted, should be discussed. The Districts were also requested to alter their normal irrigation schedule for the tests. In the Jackson School garden area, the test participants were observed aggressively throwing dirt in the direction of the filters. As much discussion as possible about the test methods would be helpful to the reader." –**El Dorado County Office of Education

ATSDR Response: Details of the specific actions followed during each of the activity scenarios are given in EPA's final Preliminary Assessment/ Site Inspection (PA/SI) report [7]. It is impossible to construct an activity scenario that exactly represents actual activity patterns. Because the concern for exposures is greatest during times when dust control measures might not occur, when windy conditions might raise up dust, or when children might throw dirt at each other, it is protective to estimate potential exposures under these conditions. Moisture content of soil at each activity scenario was measured and reported; moistures varied due to prior wetting of fields, minor rain events, and site characteristics. In the children's playground area, typical activities were conducted with no suspension of dust. For the "aggressive play" scenario, the same activities were conducted, but a leaf blower was used outside of the playground prior to activities, with fans used throughout activities to blow suspended dust towards the activities. In addition to simulating potential for exposure to dust suspended elsewhere, this is a reasonable way to attempt to simulate potentially higher exposures during aggressive play, when individuals participating in the activity scenario might not be as consistent in their actions. However, the aggressive play scenario was not used in ATSDR's exposure estimations performed in this health consultation. All child activity scenarios were performed with the sampler set at approximately 3 feet (adult scenarios were at 5 feet). Obviously, this may not perfectly represent the breathing zone for shorter or taller children.

***Request to discuss use of indirect vs. direct test method results:* "Finally, this section should also discuss whether any of the test results involved filters subject to the indirect test method. If so, the issues associated with this data should be discussed." –**El Dorado County Office of Education

ATSDR Response: Some of the sample collected by EPA were heavily loaded with solids, necessitating an "indirect" method of analysis. However, ATSDR's calculations and ATSDR-funded additional analyses were performed only on filters that were analyzed using the direct method.

***Request to clarify cleavage fragment issue:* "The excel spreadsheet uses the term "fiber level" in making the exposure assumptions. Since the ISO test method used in the 2005 Ladd study states in the abstract description that it is not capable of differentiating between fibers and cleavage fragments, our geologist informs us that it is appropriate to clarify that structures with aspect ratios greater than 3:1 were identified and therefore classified as fibers. We note this to acknowledge the current discussion in the scientific and health communities regarding the importance of distinguishing between cleavage fragments and fibers. In fact, it would be informative for the health consultation to provide an overview discussion on the current levels of uncertainties regarding health risks from cleavage fragments versus fibers, the probable pervasiveness of cleavage fragment dust in the environment, and the subjective nature of laboratory analyst structure identification considering fiber / fragment terminations, parallel sides, etc." –**El Dorado County Office of Education

ATSDR Response: For clarity of discussion, ATSDR has changed its general terminology throughout the document to refer to "structures" instead of "fibers." ATSDR considers mineral particles of interest purely on dimensional characteristic and mineral composition; we neither attempt nor accomplish any distinction between structures arising from crystal growth (fibers) versus cleavage ("cleavage fragments"). Although ATSDR supports further research into these untested mineral forms, we believe prudent public health practice does not allow so-called "cleavage fragments" to be neglected from risk calculations at this time.

It is well beyond the scope of this consultation to verify and/or address each of the above statements. The following points, however, are applicable to the El Dorado Hills situation. 1) All accepted counting methods use dimensional criteria to define which structures are to be counted; for the method used in the EPA study a modified ISO method documented all structures greater than 0.5 μm long and with an aspect ratio (length:width) of greater than or equal to 3:1. Structures fitting more restrictive dimensional criteria can later be selected from the structures counted. ATSDR's reanalysis of a subset of the EPA samples documented only structures longer than 10 μm with aspect ratios of 3:1 or greater. With such dimensional criteria, there is no need (nor is there any scientifically agreed-upon method) to differentiate between fibers and cleavage fragments of similar dimension. 2) It is generally recognized that dimensional characteristics play an important role in determining a structure's toxicity. ATSDR has not seen convincing proof that the nature of formation of a structure is a more important determinant than dimension. 3) In response to the report criticizing EPA's data as misidentifying so-called "cleavage fragments" as fibers, the EPA asked the U.S. Geological Survey to study the amphibole materials in El Dorado Hills. The USGS released a report in December 2006 and concluded that, while most of the amphibole particles examined do not meet the morphological definitions of commercial-grade asbestos, most met the counting rule criteria used by EPA from both chemical and morphological requirements. In addition, the report found "the El Dorado Hills amphiboles clearly do not fit a population of cleavage fragments…" [8]

ATSDR is currently working with other federal agencies to encourage basic research in to the toxicity of prismatic, acicular, and fibrous particles such as those present at El Dorado Hills. This research is being planned and will be conducted by the National Toxicology Program.

Suggestions for Assumptions/ Data Analysis: **"We appreciate the explanation of the assumptions used in the spreadsheet and believe it would be very helpful if this explanation were also included in the Consultation. For example, the assumptions on winter break and the winter rainy season should be explained in the front of the report. This section could also discuss issues such as whether the Grassy Field Scenario averages in the exposure from sliding into home plate or from dragging the field. We question whether averaging the data is really appropriate, since the exposure from sliding into home plate or dragging the field will occur much less frequently than the exposure from other activities during practice and it will only happen in the game of baseball." –**El Dorado County Office of Education

ATSDR Response: ATSDR will include a full explanation of the assumptions used in the text of the report and a full description of exact data used to estimate and average fiber levels. Each activity scenario had several participants, and because personal air samplers ran continuously throughout the scenario (typically 2 hours), each sample result represents an average exposure level over the two-hour period. Activities such as dragging the field took place for only a short period during the entire scenario, and the team member who slid into home base did not wear a personal sampler and performed activities for only 30 minutes of the entire scenario. Thus the results indicate the exposure that might be experienced by a general member of the team, not the actual exposure that was experienced just by the person sliding into home plate or dragging the field. Because players in soccer and other field sports slide and fall down in the course of a game, it is appropriate to apply the baseball results to all grassy field sports.

Comments on General Report Format, Analysis

Request for Additional Discussion of NOA Prevalence: **"Thank you for the opportunity to comment on the exposure assumptions that ATSDR intends to utilize in its upcoming Health Consultation Report for El Dorado Hills. Our comments are submitted in the spirit of improving the Consultation and the usefulness of the report for our community. We**

believe that a number of the comments from the El Dorado Union High School District on the Health Consultation for Oak Ridge High School should be incorporated into this Report. For example, the suggestion that ATSDR provide background information about the prevalence of NOA in California and the emergence of general population exposure to NOA as a potential public health issue is still extremely relevant and would be very helpful." –El Dorado County Office of Education

ATSDR Response: ATSDR has included discussion of the prevalence of natural deposits of asbestos (in California and elsewhere in the United States) and the recent recognition of the potential public health hazard associated with exposure to these deposits beginning on page 11 of the consultation.

***Request for Additional Discussion of Cancer Potency Slope for Asbestos:* "We also continue to believe it would be very helpful to include a concise, readable summary of the process of generating a cancer potency slope for asbestos. This discussion would be very helpful in light of the issues associated with applying existing cancer slope factors that were generated from data collected in occupational settings with high levels of asbestos to non-occupational settings with only trace levels. The discussion should describe the process of generating a cancer potency slope, the underlying cancer data utilized for the extrapolation and a very plain language explanation of the applicability of the cancer risk estimates in describing cancer risks at much lower exposure levels. We believe this is particularly important since the EPA is undertaking a major effort to update the IRIS asbestos cancer slope factor. A discussion of the underlying data utilized for the cancer potency slope factor ATSDR intends to use in this study is particularly important if the model is based upon high-level exposure to industrial grade asbestos, since those conditions are not likely to be present in El Dorado Hills.**

"The basis for the cancer potency slope and its use should be prominently presented early in the report. The early information would make interpreting the estimation of risk much easier for the lay reader. It would also be of benefit to include the formula for calculating risk based on average lifetime fiber concentration. We think it is extremely important that the report present the underlying philosophy of cancer potency slope generation and their use. We believe too many people do not understand their derivation (in general terms) and interpret risk estimates as actual risk. For example does ATSDR consider this slope factor to truly calculate the risk for low-level exposure of asbestos? The concepts we find in the 2002 ATSDR Toxicology Profile (i.e., "large degree of uncertainly in extrapolating from the available data to levels of exposure that may be several orders of magnitude lower than the current U.S. occupational exposure limit of 0.1 f/mL.") is extremely valuable. Similarly Page 18 of the Toxicology Profile states there is "considerable uncertainty in using a linear, no-threshold model for calculating health risks." We think these are important concepts that should be explained in the report." –El Dorado County Office of Education

ATSDR Response: ATSDR chose to evaluate risk using more than one asbestos risk model in this consultation. There are advantages and disadvantages to the use of any model. For each model applied, a general description of the assumptions and derivation of the model are given in the text. The uncertainty cited by the commenter is a general uncertainty in any cancer risk assessment, and its inclusion is beyond the scope of this health consultation. Further information on cancer risk assessment can be found in EPA documents [97].

Request to Discuss Berman Risk Protocol: **"As you know, the Final Draft of the Technical Support Document for a Protocol to Assess Asbestos-Related Risk prepared for the EPA by authors Dr. Wayne Berman and Kenny S. Crump examines the existing epidemiology studies to determine the relationship between asbestos exposure and response in humans, and concludes on page 1.4 that "the optimal exposure index that best reconciles the published literature assigns equal potency to fibers longer than 10 um and thinner than 0.4 um and no potency to fibers of other dimensions." If possible, we would appreciate a discussion of this finding and the applicability of the finding to data." –**El Dorado County Office of Education

ATSDR Response: In February 2003, EPA sponsored a peer consultation workshop to obtain feedback from subject matter experts on the scientific merit of the first draft (2001) of the Technical Support Document. The meeting was held in San Francisco, CA, was open to the public, and a report of the workshop is available [61]. Although the panel members were in general agreement that the proposed methodology offered the potential for substantial improvement over the existing (IRIS) methodology, they did made a number of recommendations for improving the methodology, including considering fibers with diameters up to 1.5 μm and performing further analysis to refine fiber size categories. Not all these recommendations were addressed in the final draft protocol cited by the commenter.

ATSDR agrees that dimensional and mineralogical characteristics may have an impact on toxicity of a particular structure and supports further research to elucidate chemical, physical, and toxicological relationships. However, eagerness to supply hard and fast rules of toxicity should be tempered with caution, as there are significant limitations in every existing and proposed model to date. The models are essentially derived by different types of numerical fitting of mortality/morbidity data with reconstructed historical exposures of occupational cohorts. Historical exposure data must be considered uncertain, since inaccuracies can be introduced in worker exposure level assignation; conversion of historical particle measurements to more recent fiber measurement techniques; the application of "surrogate" fiber size distribution data to describe historical worker exposures in particular industries; and selective reporting of mineral characteristics by the industries and companies involved. Mortality and morbidity data can also be uncertain due to differences in disease reporting and classification.

Complicated gradations of toxicity with changing dimensional characteristics are far more likely than the simple length/width "bins" of toxicity that have been proposed. With further research (better exposure data and more knowledge of toxicity mechanisms), the goal of finding dimensional "bins" that sufficiently describe toxicity may eventually be discovered. However, at this point it would not be protective of public health to completely dismiss potential toxicity of any elongated mineral particle that could remain in the lung for extended periods.

The Berman and Crump risk method was one of the methods evaluated in this health consultation. In order to evaluate this method, ATSDR funded additional analysis of the data to obtain greater confidence in the long structure concentrations specified for exposure measurement in the method.

Request to Describe Fiber Averaging Assumptions: **"We also believe it would be extremely helpful in the discussion to compare the assumptions used in developing the slope factor and the assumptions that will be used in the Health Consultation. For example, if you are in fact going to assume an "average" length for fibers, the issues associated with this assumption should be explained in some detail. Will you use a log-normal transformation, a median value of some non-parametric technique? Will you use different assumptions, i.e., eliminate all fibers shorter than 10 microns or wider than 0.4 microns from the count, and thus adjust the exposure estimate at the same time? The difference in the assumptions from accepted risk models should also be discussed." –**El Dorado County Office of Education

ATSDR Response: ATSDR chose to evaluate more than one asbestos risk method in this consultation. The exposure measurement definition used (i.e., the size of asbestos-related structures making up the assumed exposure) depends on the size definitions specified in the particular risk method of interest. For example, the IRIS method includes all structures meeting phase contrast microscopy dimensional criteria of greater than 5 microns long, between 0.25 and 3 microns in diameter (inclusive), and with aspect ratios (length:width) of greater than or equal to 3:1 in calculating exposure. ATSDR has included complete information on the specific size characteristics used in each method in explanatory text in the document.

"We also believe it is appropriate to consider the comments from Dr. Berman in his June 30, 2006 report to the NSSGA. A copy of his report is attached for your convenience. The conclusions on page 2 and 3 are significant. Will you use the IRIS risk factor when Dr. Berman has concluded that it will not provide reliable estimates of risk in El Dorado County if the data from the 2005 Ladd study is the basis for the assessment? Do you intend to rely upon this data before the quality control issues are resolved? It would be helpful if the issues raised by Dr. Berman were also addressed in the report." –El Dorado County Office of Education

ATSDR Response: As stated above, ATSDR chose to evaluate the data using more than one asbestos risk method in this consultation. The original data were of sufficient quality to apply most of these methods. ATSDR funded additional analysis of the sample filters to obtain more confidence in long-structure concentrations needed to apply certain of the methods, including the Berman and Crump method.

Figure F2: Original Draft Exposure Assumption Spreadsheet, Tab "Explanatory Text" **[SUPERCEDED]**

ORIGINAL DRAFT FALL 2006 - Explanatory Notes for This Workbook

This workbook contains proposed assumptions for estimating a range of potential exposures to asbestos.

The "Time-Duration" sheet contains proposed estimates of length of time spent in various activities for different age ranges.
The "Fiber Level" sheet contains the proposed methods for estimating fiber level present during each activity using results of EPA air sampling from 2004.

Duration of exposure in various activities will be combined with fiber level for each activity to obtain exposure estimates.
Exposure estimates will be uncertain due to the limited area and quantity of sampling performed.

Notes on Time-Duration Assumptions:

-Three cases are considered: Low, Medium, and High Activity
-The low activity case corresponds to a person who, throughout life, participates in very few outdoor activities. The only exposures beyond background assumed for this case are to required outdoor activities during school years.
-The medium activity case corresponds to a moderate level of participation in outdoor activities, team sports, and outdoor exercise throughout life.
-The high activity case corresponds to those who spend lots of time outdoors, participate in many team sports, and continue high level of outdoor sports and exercise activities throughout life.
-School activities are assumed to be curtailed due to summer break and the winter rainy season.
-Assumed 2 weeks of vacation to an area with no potential for exposure.
-Multiplied 12-18 year old's physical education duration by 4/7 since PE is required only 4 out of the 7 years covered in this age range.
-Background exposure duration calculated as total hours in 50 weeks minus hours of other activities.

Notes on Fiber Level Assumptions:

-We are proposing to use averages of measured fiber levels to estimate exposures.
-We will examine uncertainty/variance to determine if averages are an adequate expression of exposure.
-The values of concentration to use in calculating averages will vary depending on the fiber definition used in the model of interest.
-Asphalt Court Scenarios include all Basketball Scenarios and the Jackson Playground (4-Square) Scenario.
-Grassy Field Scenarios include all Baseball and Soccer Scenarios.
-Activities deemed to be similar to observers use stationary monitors; participants use personal monitors.

NOTE: This version is for review purposes only. We are asking for input from stakeholders to improve the accuracy of assumptions made. All values and assumptions are subject to change!

Figure F3: <u>Original</u> Draft Exposure Assumption Spreadsheet, Tab “Time-Duration” **[SUPERCEDED]**

ORIGINAL DRAFT FALL 2006 - Exposure Assumptions - El Dorado Hills NOA

******See Explanatory Text for Notes******

Case: Low Activity

Age	Activity	Hours per Week	Weeks per Year	fraction	=Hours per Year
Age: 0-4 yrs	Background		50		**8400.0**
Age: 5-11 yrs	Background		50		**8187.5**
	Recess	2.5	34		**85.0**
	PE (half asphalt, half grass)	3.75	34		**127.5**
Age: 12-18 yrs	Background		50		**8327.1**
	PE (half asphalt, half grass)	3.75	34	0.57143	**72.9**
Age: 19-30 yrs	Background		50		**8400.0**
Age: 31-70 yrs	Background		50		**8400.0**

Case: Moderate Activity

Age	Activity	Hours per Week	Weeks per Year	fraction	=Hours per Year
Age: 0-4 yrs	Background		50		**8196.0**
	Tot Lot	3	34		**102.0**
	Bicycling (alone or on parent's bike)	3	34		**102.0**
Age: 5-11 yrs	Background		50		**7777.5**
	Walking on NY Trail to & from school	2	34		**68.0**
	Recess	2.5	34		**85.0**
	PE (half asphalt, half grass)	3.75	34		**127.5**
	Asphalt courts Play	6	20		**120.0**
	Grassy Fields play	6	20		**120.0**
	New York Trail Biking/jogging	3	34		**102.0**
Age: 12-18 yrs	Background		50		**7803.1**
	Walking on NY Trail to & from school	2	34		**68.0**
	PE (half asphalt, half grass)	3.75	34	0.57143	**72.9**
	Asphalt courts Play	8	20		**160.0**
	Grassy Fields play	8	20		**160.0**
	New York Trail Biking/jogging	4	34		**136.0**
Age: 19-30 yrs	Background		50		**8200.0**
	Asphalt courts Play	2	20		**40.0**
	Grassy Fields play	2	20		**40.0**
	New York Trail Biking/jogging	3	40		**120.0**
Age: 31-70 yrs	Background		50		**8270.0**
	Asphalt courts Play	1	20		**20.0**
	Grassy Fields play	1	20		**20.0**
	New York Trail Biking/jogging	2.25	40		**90.0**

Case: High Activity

Age	Activity	Hours per Week	Weeks per Year	fraction	=Hours per Year
Age: 0-4 yrs	Background		50		**7992.0**
	Tot Lot	6	34		**204.0**
	Bicycling (alone or on parent's bike)	6	34		**204.0**
Age: 5-11 yrs	Background		50		**7262.5**
	Walking on NY Trail to & from school	2.5	34		**85.0**
	Recess	2.5	34		**85.0**
	PE (half asphalt, half grass)	3.75	34		**127.5**
	Asphalt courts Play	7	40		**280.0**
	Grassy Fields play	7	40		**280.0**
	New York Trail Biking/jogging	7	40		**280.0**
Age: 12-18 yrs	Background		50		**7738.1**
	Walking on NY Trail to & from school	2.5	34		**85.0**
	PE (half asphalt, half grass)	3.75	34	0.57143	**72.9**
	Asphalt courts Play	14	12		**168.0**
	Grassy Fields play	14	12		**168.0**
	New York Trail Biking/jogging	14	12		**168.0**
Age: 19-30 yrs	Background		50		**8000.0**
	Asphalt courts Play	4	20		**80.0**
	Grassy Fields play	4	20		**80.0**
	New York Trail Biking/jogging	6	40		**240.0**
Age: 31-70 yrs	Background		50		**7920.0**
	Asphalt courts Play	6	20		**120.0**
	Grassy Fields play	6	20		**120.0**
	New York Trail Biking/jogging	6	40		**240.0**

Figure F4: Original Draft Exposure Assumption Spreadsheet, Tab "Fiber Level" **[SUPERCEDED]**

ORIGINAL DRAFT FALL 2006 - Proposed Method to Estimate Fiber Level for Various Activities and Ages

******See Explanatory Text for Notes******

Child Activities (Up to 18 Years Old)

Activity	Proposed Scenario to Describe Exposure During Activity	Proposed Estimate of Fiber Level During Activity
Background	Reference Stations	Average of all reference stations
Tot Lot	Typical Activity Scenario at Tot Lot	Average of personal monitors for child participant in this scenario
Bicycling (alone or on parent's bike)	Biking Scenario on NY Trail (assume similar for other activities on trail)	Average of personal monitors for child participant in this scenario
Walking on NY Trail to & from school	Biking and Jogging Scenarios on NY Trail (assume similar to observer exposure)	Average of stationary monitor samples for these scenarios
Recess	Grassy Field and Asphalt Court Scenarios (assume similar to observer exposure)	Average of all stationary monitor samples for these scenarios
Physical Education	Grassy Field and Asphalt Court Scenarios (assume equal contribution)	Average of personal monitors for child participant in these scenarios
Asphalt Courts Play	Asphalt Court Scenarios	Average of personal monitors for child participant in these scenarios
Grassy Fields Play	Grassy Field Scenarios	Average of personal monitors for child participant in these scenarios
New York Trail Biking/jogging	Biking Scenario on NY Trail (assume similar for other activities on trail)	Average of personal monitors for child participant in this scenario

Adult Activities (Ages 19-70 Years Old)

Activity	Proposed Scenario to Describe Exposure During Activity	Proposed Estimate of Fiber Level During Activity
Background	Reference Stations	Average of all reference stations
Asphalt Courts Play	Asphalt Court Scenarios	Average of personal monitors for child participants and adult nonparticipants (no data on adult participants)
Grassy Fields Play	Grassy Field Scenarios	Average of personal monitors for adult participants in these scenarios
New York Trail Biking/jogging	Jogging Scenario on NY Trail (assume similar for other activities on trail)	Average of personal monitors for adult participants in this scenario

Figure F5: Revised Exposure Assumption Spreadsheet, Tab "Explanatory Notes"
(Note: Tabs "Time-Duration" and "Fiber Level" are summarized in the body of the text as Tables 1 and 2.)

REVISED Explanatory Notes for This Workbook

This workbook contains assumptions for estimating a range of potential exposures to asbestos.
The "Time-Duration" sheet contains estimates of length of time spent in various activities for different age ranges.
The "Fiber Level" sheet contains the methods used to estimate fiber level present during each activity using results of EPA air sampling from 2004.
Duration of exposure in various activities is combined with fiber level for each activity to obtain exposure estimates.
Exposure estimates will be uncertain due to the limited area and quantity of sampling performed.

Notes on Time-Duration Assumptions:
-Three cases are considered: Low, Medium, and High Activity
-The low activity case corresponds to a person who, throughout life, participates in very few outdoor activities. The only exposures beyond background assumed for this case are to required outdoor activities during school years.
-The moderate activity case corresponds to a moderate level of participation in outdoor activities, team sports, and outdoor exercise throughout life.
-The high activity case corresponds to those who spend lots of time outdoors, participate in many team sports, and continue high level of outdoor sports and exercise activities throughout life.
-Assumed 2 weeks of vacation to an area with no potential for exposure for a total year of 50 weeks.
-Subtracted 13 week "wet" period (see explanation in school time-duration section below) from 50-week year to obtain "dry" exposure duration assumption of 37 weeks.

School Time-Duration Assumptions:
-School year consists of 180 days (CA law) and runs from mid-August to early June. Assumed 45 weeks of school year. (School breaks included.)
-"Wet" period assumed to have lower background levels of asbestos =13 weeks (based on local construction data, NOAA and weather.com reports).
-Subtracted 13 weeks from 45-week school year to obtain "dry" school year of 32 weeks (for physical education, etc.).
-Assumed 1 hour per week of "digging" for 5-11 year-old's gardening activities at school, only during "dry" times.
-Multiplied 12-18 year old's physical education duration by 4/7 since PE is required only 4 out of the 7 years covered in this age
-Assumed 3 weeks of "digging" for 12-18 year-old's soil science experiments; multiplied by 4/7 since science assumed to be taken 4 out of the 7 years covered in this age range.
-"Dry" background exposure duration calculated as total hours in 50 weeks minus "wet" periods minus hours of other activities.
-Assumed time spent in extracurricular activities split between grassy fields, asphalt courts, and NY Creek Trail ("seasons" or average indicated by weeks per year, total adds up to 36-weeks to include the "dry" school year plus 4 weeks during the summer.) 5-11 year olds have greater proportion of activities on fields & courts.
-For children and adolescents, hours of extracurricular activity averages just under 1 hour per school day for the "moderate" scenario and slightly less than 2 hours per school day for the "high" scenario. The Surgeon General recommends a minimum of 1 hour of physical activity on most days for children and adolescents.

Notes on Fiber Level Assumptions:
-Assume reference stations describe "dry" background levels.
-Assume "wet" periods are described by a value one-tenth that of the "dry" reference station levels. (Supporting info=local construction data, CARB data - see text.)
-Annual average exposure concentrations used scenario averages in mid-range estimates and scenario maximums for high-end estimates. In all calculations, non-detects were counted as zero.
-The values of concentration to use in determining averages/ maximums varies depending on the fiber definition used in the method of interest.
-Asphalt Court Scenarios include all Basketball Scenarios and the Jackson Playground (4-Square) Scenario.
-Grassy Field Scenarios include all Baseball and Soccer Scenarios.
-Activities deemed to be similar to observers use stationary monitors; participants use personal monitors.
-Use of direct measurement data only.

Appendix G. Tabulated Selected Detailed Data and Results

Table G1. Average and Maximum Structure Levels for Each Activity Scenario.

Activity	AHERA 3:1 - All samples analyzed by EPA (s/cc)		PCMe - All samples analyzed by EPA (f/cc)		AHERA 3:1 - Only Those Samples Selected for Additional Analysis (s/cc)		PCMe - Only Those Samples Selected for Additional Analysis (f/cc)		Protocol Chrysotile - From Additional Analysis (s/cc)		Protocol Amphibole - From Additional Analysis (s/cc)	
row index # -->	2	3	4	5	6	7	8	9	10	11	12	13
	average	maximum	average	maximum	average	maximum	average	maximum	average	maximum	average	maximum
Adult - Asphalt Courts Play	0.005	0.01	0.002	0.005	0.007	0.01	0.003	0.005	0	0	0	0
Adult - Dry Background	0.002	0.006	0.0008	0.004	0.002	0.006	0.0008	0.004	0.000003	0.00008	0.00002	0.0001
Adult - Grassy Fields Play	0.02	0.1	0.004	0.02	0.03	0.1	0.008	0.02	0	0	0.0001	0.001
Adult - New York Trail Biking/jogging	0.04	0.1	0.02	0.06	0.05	0.1	0.03	0.06	0	0	0.0003	0.002
Adult - Wet Background	0.0002	0.0006	0.0001	0.0004	0.0002	0.0006	0.0001	0.0004	0.0000003	0.000008	0.000002	0.00001
Child - "Digging"	0.002	0.003	0.0003	0.001	0.003	0.003	0.001	0.001	0	0	0	0
Child - Asphalt Courts Play	0.006	0.01	0.002	0.005	0.007	0.01	0.003	0.005	0	0	0	0
Child - Bicycling (alone or on parent's bike)	0.06	0.1	0.03	0.08	0.09	0.1	0.05	0.08	0	0	0	0
Child - Dry Background	0.002	0.006	0.0008	0.004	0.002	0.006	0.0008	0.004	0.000003	0.00008	0.00002	0.0001
Child - Grassy Fields Play	0.07	0.8	0.007	0.03	0.1	0.8	0.009	0.03	0.0002	0.004	0.0003	0.001
Child - New York Trail Biking/jogging	0.06	0.1	0.03	0.08	0.09	0.1	0.05	0.08	0	0	0	0
Child - Physical Education	0.05	0.8	0.005	0.03	0.08	0.8	0.008	0.03	0.0001	0.004	0.0002	0.001
Child - Recess	0.02	0.3	0.002	0.02	0.02	0.2	0.004	0.02	0.00003	0.0006	0.0001	0.0006
Child - Tot Lot	0.02	0.3	0.003	0.01	0.04	0.3	0.005	0.01	0.00004	0.0003	0.0001	0.001
Child - Walking on NY Trail to & from school	0.006	0.04	0.003	0.02	0.010	0.04	0.006	0.02	0	0	0.00004	0.0004
Child - Wet Background	0.0002	0.0006	0.00008	0.0004	0.0002	0.0006	0.0001	0.0004	0.0000003	0.000008	0.000002	0.00001

NOTES

Average concentration value for each scenario used to estimate "mid-range" annual average exposure concentration.
Maximum value for each scenario used to estimate "high-end" annual average exposure concentration.

Table G2. Mid-range and High-end Estimated Annual Average Structure Concentrations

Annual Averages Including All Samples Analyzed by EPA

	PCMe f/cc (All)					
	Mid-range estimate			High-end estimate		
	Activity Level			Activity Level		
Age	Low	Moderate	High	Low	Moderate	High
0-4 yrs	0.0006	0.0011	0.0015	0.0034	0.0045	0.0055
5-11 yrs	0.0007	0.0009	0.0011	0.0038	0.0044	0.0050
12-18 yrs	0.0006	0.0010	0.0012	0.0035	0.0044	0.0051
19-30 yrs	0.0006	0.0008	0.0010	0.0033	0.0039	0.0044
31-120 yrs	0.0006	0.0007	0.0010	0.0033	0.0037	0.0043
lifetime average	0.0006	0.0008	0.0010	0.0033	0.0039	0.0045

Annual Averages Including Only Those Samples Selected for Additional Analysis by ATSDR

	PCMe f/cc (Selected)					
	Mid-range estimate			High-end estimate		
	Activity Level			Activity Level		
Age	Low	Moderate	High	Low	Moderate	High
0-4 yrs	0.0006	0.0013	0.0020	0.0034	0.0045	0.0055
5-11 yrs	0.0007	0.0011	0.0014	0.0038	0.0044	0.0050
12-18 yrs	0.0007	0.0011	0.0016	0.0035	0.0044	0.0051
19-30 yrs	0.0006	0.0009	0.0011	0.0033	0.0039	0.0044
31-120 yrs	0.0006	0.0008	0.0011	0.0033	0.0037	0.0043
lifetime average	0.0006	0.0009	0.0012	0.0033	0.0039	0.0045

Annual Averages Including All Samples Analyzed by EPA

	Total TEM s/cc (3:1 Aspect Ratio, All)					
	Mid-range estimate			High-end estimate		
	Activity Level			Activity Level		
Age	Low	Moderate	High	Low	Moderate	High
0-4 yrs	0.002	0.003	0.004	0.005	0.010	0.015
5-11 yrs	0.002	0.003	0.004	0.019	0.026	0.033
12-18 yrs	0.002	0.003	0.004	0.011	0.018	0.024
19-30 yrs	0.002	0.002	0.002	0.005	0.006	0.007
31-120 yrs	0.002	0.002	0.002	0.005	0.006	0.007
lifetime average	0.002	0.002	0.003	0.006	0.008	0.010

Annual Averages Including Only Those Samples Selected for Additional Analysis by ATSDR

	Total TEM s/cc (3:1 Aspect Ratio, Selected))					
	Mid-range estimate			High-end estimate		
	Activity Level			Activity Level		
Age	Low	Moderate	High	Low	Moderate	High
0-4 yrs	0.002	0.003	0.005	0.005	0.010	0.015
5-11 yrs	0.003	0.004	0.005	0.018	0.025	0.032
12-18 yrs	0.002	0.004	0.005	0.011	0.018	0.024
19-30 yrs	0.002	0.002	0.003	0.005	0.006	0.007
31-120 yrs	0.002	0.002	0.003	0.005	0.006	0.007
lifetime average	0.002	0.002	0.003	0.006	0.008	0.010

Annual Averages for "Protocol" Structures Determined from Samples Selected for Additional Analysis by ATSDR

	Amphibole Protocol Fibers						Chrysotile Protocol Fibers					
	Mid-range estimate			High-end estimate			Mid-range estimate			High-end estimate		
	Activity Level			Activity Level			Activity Level			Activity Level		
Age	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
0-4 yrs	0.000017	0.000018	0.000019	0.00010	0.00011	0.00012	0.000002	0.000003	0.000003	0.00006	0.00006	0.00006
5-11 yrs	0.000020	0.000022	0.000024	0.00012	0.00013	0.00014	0.000005	0.000006	0.000008	0.00012	0.00015	0.00018
12-18 yrs	0.000019	0.000020	0.000022	0.00011	0.00012	0.00012	0.000003	0.000005	0.000006	0.00009	0.00012	0.00014
19-30 yrs	0.000016	0.000020	0.000022	0.00010	0.00012	0.00013	0.000002	0.000002	0.000002	0.00006	0.00006	0.00006
31-120 yrs	0.000016	0.000019	0.000022	0.00010	0.00011	0.00013	0.000002	0.000002	0.000002	0.00006	0.00006	0.00006

NOTES

Mid-range estimate uses average concentration value for each scenario in calculating annual average across all scenarios.
High-end estimate uses highest concentration value for each scenario in calculating annual average across all scenarios.

Table G3. 2003 All-Cause Death Rates Used in Life Table Analysis (Source: [76]).

Age	Males		Females	
	Probability of Dying Between Year x and x+1 (from Table 2. Life Table for Males, United States, 2003)	Unexposed Death Rate (from solving Equation D3, equals -ln(1-probability of dying))	Probability of Dying Between Year x and x+1 (from Table 3. Life Table for Females, United States, 2003)	Unexposed Death Rate (from solving Equation D3, equals -ln(1-probability of dying))
0-1	0.007611	0.00764	0.006083	0.00610
1-2	0.000518	0.00052	0.00041	0.00041
2-3	0.000365	0.00037	0.000296	0.00030
3-4	0.000293	0.00029	0.000223	0.00022
4-5	0.00022	0.00022	0.000175	0.00018
5-6	0.000192	0.00019	0.000143	0.00014
6-7	0.000173	0.00017	0.000127	0.00013
7-8	0.000152	0.00015	0.000132	0.00013
8-9	0.000157	0.00016	0.000121	0.00012
9-10	0.000138	0.00014	0.000129	0.00013
10-11	0.000186	0.00019	0.000143	0.00014
11-12	0.000162	0.00016	0.000132	0.00013
12-13	0.000217	0.00022	0.000133	0.00013
13-14	0.000255	0.00026	0.000164	0.00016
14-15	0.000334	0.00033	0.000176	0.00018
15-16	0.00043	0.00043	0.000243	0.00024
16-17	0.000706	0.00071	0.000353	0.00035
17-18	0.000908	0.00091	0.000399	0.00040
18-19	0.001212	0.00121	0.000494	0.00049
19-20	0.001356	0.00136	0.000465	0.00047
20-21	0.001395	0.00140	0.000486	0.00049
21-22	0.001412	0.00141	0.000489	0.00049
22-23	0.001444	0.00145	0.000505	0.00051
23-24	0.001388	0.00139	0.000495	0.00050
24-25	0.001373	0.00137	0.000514	0.00051
25-26	0.001326	0.00133	0.000494	0.00049
26-27	0.00136	0.00136	0.000547	0.00055
27-28	0.001317	0.00132	0.000566	0.00057
28-29	0.001301	0.00130	0.000549	0.00055
29-30	0.001367	0.00137	0.000618	0.00062
30-31	0.001393	0.00139	0.000626	0.00063
31-32	0.001416	0.00142	0.000669	0.00067
32-33	0.001521	0.00152	0.000693	0.00069
33-34	0.001505	0.00151	0.000799	0.00080
34-35	0.001596	0.00160	0.000852	0.00085
35-36	0.001732	0.00173	0.000977	0.00098
36-37	0.001876	0.00188	0.00104	0.00104
37-38	0.002008	0.00201	0.001141	0.00114
38-39	0.002126	0.00213	0.001216	0.00122
39-40	0.002341	0.00234	0.001356	0.00136
40-41	0.002535	0.00254	0.001521	0.00152
41-42	0.0028	0.00280	0.001635	0.00164
42-43	0.00304	0.00304	0.001795	0.00180
43-44	0.003231	0.00324	0.001876	0.00188
44-45	0.003582	0.00359	0.002125	0.00213
45-46	0.003777	0.00378	0.002261	0.00226
46-47	0.004278	0.00429	0.002486	0.00249
47-48	0.004598	0.00461	0.002613	0.00262
48-49	0.004926	0.00494	0.00278	0.00278
49-50	0.005356	0.00537	0.00304	0.00304

Age	Males		Females	
	Probability of Dying Between Year x and x+1 (from Table 2. Life Table for Males, United States, 2003)	Unexposed Death Rate (from solving Equation D3, equals -ln(1-probability of dying))	Probability of Dying Between Year x and x+1 (from Table 3. Life Table for Females, United States, 2003)	Unexposed Death Rate (from solving Equation D3, equals -ln(1-probability of dying))
50-51	0.005773	0.00579	0.003264	0.00327
51-52	0.006153	0.00617	0.003508	0.00351
52-53	0.006633	0.00666	0.003829	0.00384
53-54	0.006813	0.00684	0.003978	0.00399
54-55	0.007688	0.00772	0.004502	0.00451
55-56	0.007986	0.00802	0.004759	0.00477
56-57	0.009095	0.00914	0.005466	0.00548
57-58	0.008825	0.00886	0.005474	0.00549
58-59	0.010289	0.01034	0.006512	0.00653
59-60	0.011298	0.01136	0.007104	0.00713
60-61	0.012631	0.01271	0.007979	0.00801
61-62	0.013049	0.01313	0.00815	0.00818
62-63	0.014841	0.01495	0.009356	0.00940
63-64	0.015666	0.01579	0.010029	0.01008
64-65	0.017184	0.01733	0.11201	0.11879
65-66	0.018456	0.01863	0.011923	0.01199
66-67	0.020034	0.02024	0.012895	0.01298
67-68	0.021998	0.02224	0.0144225	0.01453
68-69	0.023697	0.02398	0.015455	0.01558
69-70	0.026257	0.02661	0.016688	0.01683
70-71	0.028427	0.02884	0.01889	0.01907
71-72	0.030325	0.03079	0.020078	0.02028
72-73	0.033933	0.03452	0.022156	0.02241
73-74	0.036781	0.03747	0.024088	0.02438
74-75	0.039863	0.04068	0.026516	0.02687
75-76	0.04446	0.04548	0.02915	0.02958
76-77	0.048518	0.04973	0.032215	0.03275
77-78	0.052622	0.05406	0.035695	0.03635
78-79	0.057085	0.05878	0.038807	0.03958
79-80	0.062847	0.06491	0.043098	0.04405
80-81	0.069652	0.07220	0.048423	0.04963
81-82	0.075675	0.07869	0.053033	0.05449
82-83	0.081382	0.08488	0.05839	0.06016
83-84	0.094027	0.09875	0.067373	0.06975
84-85	0.095172	0.10001	0.069965	0.07253
85-86	0.103762	0.10955	0.077121	0.08026
86-87	0.113017	0.11993	0.084936	0.08876
87-88	0.122971	0.13122	0.093453	0.09811
88-89	0.133651	0.14347	0.102719	0.10839
89-90	0.145087	0.15676	0.112778	0.11966
90-91	0.157299	0.17114	0.123671	0.13201
91-92	0.170307	0.18670	0.135439	0.14553
92-93	0.184124	0.20349	0.148116	0.16030
93-94	0.198755	0.22159	0.161733	0.17642
94-95	0.214201	0.24105	0.176314	0.19397
95-96	0.230452	0.26195	0.191874	0.21304
96-97	0.247491	0.28434	0.208419	0.23372
97-98	0.265289	0.30828	0.225945	0.25611
98-99	0.283809	0.33381	0.244433	0.28029
99-100	0.303003	0.36097	0.263854	0.30633
100+	1	*extend above death rate out to age 120	1	*extend above death rate out to age 120

Table G4. 2003 Lung Cancer Death Rates Used in Life Table Analysis (Source: [75]).

Age	Males		Females	
	Lung Cancer Death Rate per 100,000 (from Worktable 210R, 2003	Lung Cancer Death Rate	Lung Cancer Death Rate per 100,000 (from Worktable 210R, 2003	Lung Cancer Death Rate
0-1	0	0	0	0
1-2	0	0	0	0
2-3	0	0	0	0
3-4	0	0	0	0
4-5	0	0	0	0
5-6	0	0	0	0
6-7	0	0	0	0
7-8	0	0	0	0
8-9	0	0	0	0
9-10	0	0	0	0
10-11	0	0	0	0
11-12	0	0	0	0
12-13	0	0	0	0
13-14	0	0	0	0
14-15	0	0	0	0
15-16	0	0	0	0
16-17	0	0	0	0
17-18	0	0	0	0
18-19	0	0	0	0
19-20	0	0	0	0
20-21	0	0	0	0
21-22	0	0	0	0
22-23	0	0	0	0
23-24	0	0	0	0
24-25	0	0	0	0
25-26	0	0	0.2	0.000002
26-27	0	0	0.2	0.000002
27-28	0	0	0.2	0.000002
28-29	0	0	0.2	0.000002
29-30	0	0	0.2	0.000002
30-31	0.7	0.000007	0.5	0.000005
31-32	0.7	0.000007	0.5	0.000005
32-33	0.7	0.000007	0.5	0.000005
33-34	0.7	0.000007	0.5	0.000005
34-35	0.7	0.000007	0.5	0.000005
35-36	2.4	0.000024	2.5	0.000025
36-37	2.4	0.000024	2.5	0.000025
37-38	2.4	0.000024	2.5	0.000025
38-39	2.4	0.000024	2.5	0.000025
39-40	2.4	0.000024	2.5	0.000025
40-41	9.5	0.000095	7.5	0.000075
41-42	9.5	0.000095	7.5	0.000075
42-43	9.5	0.000095	7.5	0.000075

Age	Males		Females	
	Lung Cancer Death Rate per 100,000 (from Worktable 210R, 2003	Lung Cancer Death Rate	Lung Cancer Death Rate per 100,000 (from Worktable 210R, 2003	Lung Cancer Death Rate
43-44	9.5	0.00010	7.5	0.000075
44-45	9.5	0.00010	7.5	0.00008
45-46	24.8	0.00025	17.8	0.00018
46-47	24.8	0.00025	17.8	0.00018
47-48	24.8	0.00025	17.8	0.00018
48-49	24.8	0.00025	17.8	0.00018
49-50	24.8	0.00025	17.8	0.00018
50-51	50.0	0.00050	31.9	0.00032
51-52	50.0	0.00050	31.9	0.00032
52-53	50.0	0.00050	31.9	0.00032
53-54	50.0	0.00050	31.9	0.00032
54-55	50.0	0.00050	31.9	0.00032
55-56	101.3	0.0010	63.5	0.00064
56-57	101.3	0.0010	63.5	0.00064
57-58	101.3	0.0010	63.5	0.00064
58-59	101.3	0.0010	63.5	0.00064
59-60	101.3	0.0010	63.5	0.00064
60-61	183.7	0.0018	117.4	0.0012
61-62	183.7	0.0018	117.4	0.0012
62-63	183.7	0.0018	117.4	0.0012
63-64	183.7	0.0018	117.4	0.0012
64-65	183.7	0.0018	117.4	0.0012
65-66	292.1	0.0029	176.2	0.0018
66-67	292.1	0.0029	176.2	0.0018
67-68	292.1	0.0029	176.2	0.0018
68-69	292.1	0.0029	176.2	0.0018
69-70	292.1	0.0029	176.2	0.0018
70-71	411.0	0.0041	236.1	0.0024
71-72	411.0	0.0041	236.1	0.0024
72-73	411.0	0.0041	236.1	0.0024
73-74	411.0	0.0041	236.1	0.0024
74-75	411.0	0.0041	236.1	0.0024
75-76	514.2	0.0051	277.9	0.0028
76-77	514.2	0.0051	277.9	0.0028
77-78	514.2	0.0051	277.9	0.0028
78-79	514.2	0.0051	277.9	0.0028
79-80	514.2	0.0051	277.9	0.0028
80-81	541.5	0.0054	281.4	0.0028
81-82	541.5	0.0054	281.4	0.0028
82-83	541.5	0.0054	281.4	0.0028
83-84	541.5	0.0054	281.4	0.0028
84-85	541.5	0.0054	281.4	0.0028
85+	475.1	0.0048	221.0	0.0022

Appendix H. ATSDR Fact Sheets

"Limiting Environmental Exposure to Asbestos in Areas With Naturally Occurring Asbestos"; "Asbestos For Workers Involved in Activities That Disturb Soil or Generate Dust in Areas With Naturally Occurring Asbestos"

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

This fact sheet was written by the **Agency for Toxic Substances and Disease Registry** (ATSDR), a federal public health agency. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposure and disease related to toxic substances.

Asbestos

Limiting Environmental Exposure to Asbestos in Areas with Naturally Occurring Asbestos

Who should read this fact sheet

Read this fact sheet if you or someone you know currently lives, works, attends school, or plays in areas with asbestos in the soils, or has done so in the past.

Purpose of this fact sheet

This fact sheet answers the following questions:

- What is asbestos?
- How could asbestos exposure make you sick?
- What can you do to reduce your exposure to asbestos?
- Where can you get more information?

What is asbestos?

Asbestos defined

Asbestos is the name given to a group of six different fibrous minerals that occur naturally in the environment. Asbestos fibers are too small to be seen by the naked eye. They do not dissolve in water or evaporate. They are resistant to heat, fire, and chemical or biological degradation.

Naturally occurring asbestos refers to those fibrous minerals that are found in the rocks or soil in an area and released into the air by:

- routine human activities or
- weathering processes.

If naturally occurring asbestos is not disturbed and fibers are not released into the air, then it is not a health risk. Asbestos is used in many commercial products, including insulation, brake linings, and roofing shingles.

Classes of asbestos

The two general classes of asbestos are amphibole and chrysotile (fibrous serpentine). Chrysotile asbestos has long, flexible fibers. This type of asbestos is most commonly used in commercial products. Amphibole fibers are brittle, have a rod or needle shape, and are less common in commercial products. Although exposure to both types of asbestos increases the likelihood of developing asbestos-related illness, amphibole fibers tend to stay in the lungs longer. They also are thought to increase the likelihood of illness, especially mesothelioma, to a greater extent than chrysotile asbestos.

05-0278

Where asbestos is found in your environment

Asbestos is commonly found in ultramafic rock, including serpentine rock, and near fault zones. The amount of asbestos that is typically present in these rocks ranges from less than 1% up to about 25%, and sometimes more. Asbestos can be released from ultramafic and serpentine rock if the rock is broken or crushed.

In California, ultramafic rock, including serpentine rock, is found in the Sierra foothills, the Klamath Mountains, and the Coast Ranges. This type of rock is present in at least 44 of California's 58 counties. Not all ultramafic rock contains asbestos, it only has the potential to contain asbestos. Environmental testing can determine if a rock contains asbestos.

How you might be exposed to asbestos

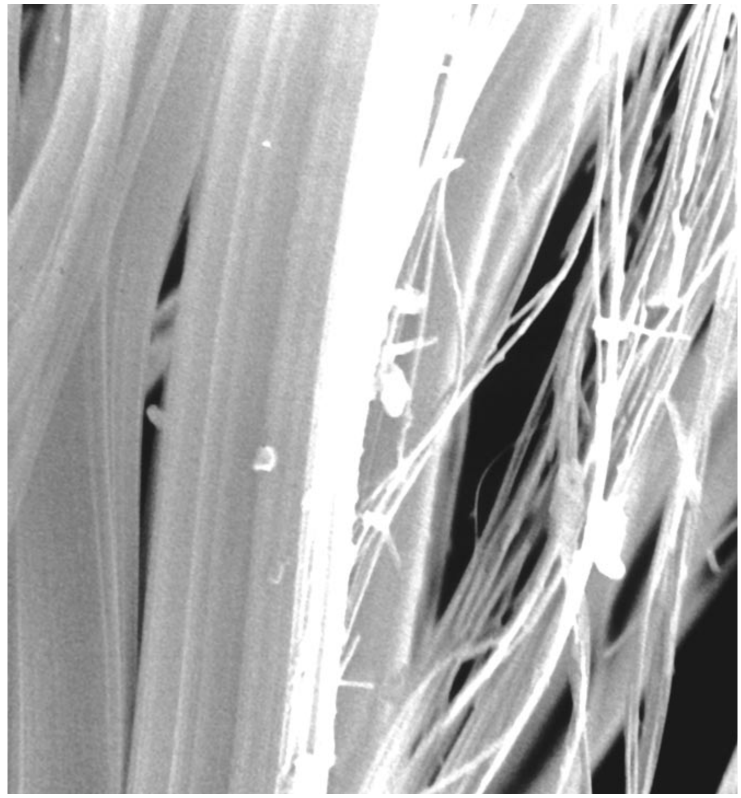
You might be exposed to asbestos through routine activities that crush asbestos-containing rock or stir up dust in soils that contain asbestos fibers. The following are some examples of these activities:

- Working in your yard or garden
- Digging or shoveling dirt
- Riding bicycles on unpaved surfaces
- Riding off-road vehicles such as four wheelers and dirt bikes
- Running and hiking on unpaved surfaces
- Driving over unpaved surfaces

How could asbestos exposure make you sick?

Important!

Being exposed to asbestos does not mean you will develop health problems. Many things need to be considered when evaluating whether you are at risk for health problems from asbestos exposure. A doctor can help you find out whether you are at risk for health problems from asbestos exposure.



Magnification of Asbestos Fibers Ê

Asbestos exposure and health

Asbestos is made up of fibers that are so small that you cannot see them. If asbestos fibers are in the air you breathe, you might get asbestos fibers in your lungs. Breathing in the fibers is the primary way that people are exposed to asbestos.

Asbestos fibers may remain in the lungs for a lifetime. In some cases, the fibers might damage the lungs or the membranes that cover the lungs, leading to illness and even death. Most people don't show any signs or symptoms of asbestos-related disease until 10 to 20 years or more after they were exposed.

For more information about asbestos-related disease, refer to ATSDR's fact sheet entitled:
"Asbestos and Health: Frequently Asked Questions"

What can you do to reduce your exposure to asbestos?

Take steps right now

Limit exposure by taking the following steps if you live in an area where naturally occurring asbestos has been disturbed and is likely to become airborne:

- Walk, run, hike, and bike only on paved trails. Ê
- Play only in outdoor areas with a ground covering such as wood chips, mulch, sand, pea gravel, grass, asphalt, shredded rubber, or rubber mats. Ê
- Pave over unpaved walkways, driveways, or roadways that may have asbestos-containing rock or soil. Ê
- Cover asbestos-containing rock or soil in gardens and yards with asbestos-free soil or landscape covering. Ê
- Pre-wet garden areas before digging or shoveling soil. Ê
- Keep pets from carrying dust or dirt on their fur or feet into the home. Ê
- Remove shoes before entering your home to prevent tracking in dirt. Ê
- Use doormats to lower the amount of soil that is tracked into the home. Ê
- Keep windows and doors closed on windy days and during nearby construction. Ê
- Drive slowly over unpaved roads. Ê
- Use a wet rag instead of a dry rag or duster to dust. Ê
- Use a wet mop on non-carpeted floors. Ê
- Use washable area rugs on your floors and wash rugs regularly. Ê
- Vacuum your carpet often using a vacuum with a high efficiency HEPA filter. Ê

Where can you get more information?

Stay informed

If you want more information about how to limit environmental exposure to asbestos, or if you have specific questions, contact ATSDR:

Toll free call:
1-888-42-ATSDR (1-888-422-8737)

Online:
http://www.atsdr.cdc.gov/contactus.html

Some of the information in this fact sheet comes from the brochure Asbestos-Containing Rock and Soil—What California Homeowners and Renters Need to Know, California Air Resources Board, 2002. Accessed online at http://www.arb.ca.gov/cap/pamphlets/asbestosbrochure.pdf on April 26, 2005.

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Department of Health and Human Services

Agency for Toxic Substances and Disease Registry

This fact sheet was prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR's mission is to serve 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.

Asbestos

For workers involved in activities that disturb soil or generate dust in areas with naturally occurring asbestos.

Who should read this fact sheet?

This fact sheet is for people in El Dorado County, California who work or have worked outdoors in areas where asbestos has been found in the soil. Some of this information may apply to other locations where naturally occurring asbestos is present.

Purpose of this fact sheet

This fact sheet addresses common asbestos-related concerns, such as:

- How do you find out if asbestos is a problem in your work area ?
- Who do you contact if you suspect a problem with asbestos at work?
- How can you be exposed to asbestos at work?
- How can you protect yourself from asbestos at work?

Limiting Asbestos Exposure While Working in Areas with Naturally Occurring Asbestos

What is asbestos?

Asbestos defined

Asbestos is a group of fibrous minerals that occur naturally in rock formations. Asbestos fibers are too small to be seen by the naked eye. They do not dissolve in water or evaporate. They resist heat, fire, and chemical or biological degradation. Because of these properties, asbestos has been mined and used in many commercial products including insulation, fireproofing and acoustic materials, wallboard, plaster, cement, floor tiles, brake linings, and roofing shingles.

Naturally occurring asbestos

Naturally occurring asbestos refers to those fibrous minerals that are found in the rocks or soil in some areas and released into the air by routine human activities or weathering processes. *If naturally occurring asbestos is not disturbed and fibers are not released into the air, then it is not a health risk.*

Where asbestos is found in your environment

Asbestos is commonly found in ultramafic rock, including serpentine rock, and near fault zones. The typical amount of asbestos in these rocks ranges from less than 1% to 25%. Asbestos can be released into the air or soil if the rock is broken or crushed.

In California, ultramafic rock, including serpentine rock, is found in the Sierra foothills, the Klamath Mountains, and the Coast Ranges. This type of rock is present in at least 44 of California's 58 counties. Not all ultramafic rock contains asbestos. Environmental testing can determine if a rock contains asbestos.

How can you find out if a problem exists in your work area?

Who to contact to find out if a problem exists

To learn if you work in an area that might have naturally occurring asbestos, consult the following agencies:

1. California Geological Survey provides information on the geology of asbestos occurrences in California. http://www.consrv.ca.gov/cgs/minerals/hazardous_minerals/asbestos/index.htm

2. El Dorado County Environmental Management Department http://www.co.el-dorado.ca.us/emd/apcd/asbestos.html.

These agencies can assist with understanding the current conditions in your area. **If asbestos is present in an area, but it is not disturbed by human activity or construction, then it is not a health risk.**

How to find out if asbestos is present in a work area

If you work in an area with naturally occurring asbestos, the only way to know if asbestos is present where you work is to test your work area. The Occupational Safety and Health Administration's (OSHA) asbestos standards need to be followed when working with asbestos. More information is posted on the OSHA Internet page at:

http://www.osha.gov/SLTC/asbestos/index.html

Material that contains asbestos is not a health risk if it is undisturbed or covered. It can be a hazard if it becomes friable (crumbly) and airborne.

How can you be exposed to asbestos?

How you might be exposed to asbestos

Limit activities that create dusty conditions near asbestos containing soil. You might be exposed to asbestos through activities that crush asbestos-containing rock or stir up dust in soils that contain asbestos in your work area. The following are some examples of activities that might result in exposure if they create dusty conditions:

- Working in a garden
- Digging or shoveling dirt
- Landscaping
- Sweeping or leaf blowing
- Plowing or planting
- Excavating or using a backhoe
- Rock drilling or using a jackhammer
- Driving over unpaved surfaces
- Walking or running on gravel roads
- Running underground cable or pipe
- Disturbing dirt on unpaved surfaces
- Felling trees because it disturbs dirt
- Blasting, chipping, hammering, drilling, crushing, loading, hauling, and dumping rock
- Working near a helicopter that is creating dusty conditions
- Working in railroad construction or maintenance
- Working in highway construction or maintenance
- Operating heavy equipment where the soil contains asbestos fibers
- Engaging in any activity that disturbs the soil or crushes rocks that contain asbestos

Types of workers who may be exposed to naturally occurring asbestos

Any activity that creates dust or disturbs soil in an area where asbestos is present can cause exposure to asbestos. Construction workers and excavators have jobs that could expose them to asbestos. These include backhoe, crane, tractor, and other heavy equipment operators. Miners, rock drillers or jackhammer operators, demolition workers, bricklayers, stone workers, and cement workers also have jobs that could expose them to asbestos. Other people who might be exposed to asbestos on-the-job include utility workers, lumberjacks, foundry workers, and gravel pit operators.

Highway and railroad construction or maintenance workers also may be at risk. The list also includes outdoor sports instructors and playground workers, outdoor maintenance workers, farmers and nursery workers, landscapers, and others.

What can you do to reduce potential asbestos exposure?

Take steps to avoid dusty conditions and reduce exposure

Workers should take steps to limit the generation and inhalation of dust known or thought to be contaminated by asbestos. As with any dust, workers should avoid prolonged high-level exposures. If you work in areas that contain naturally occurring asbestos that can become airborne and creates dusty conditions, limit your exposure by taking some of the following steps:

- Use wet methods to reduce airborne exposure. Wet the soil before gardening or planting. Wet down dusty areas when operating a jackhammer or when cleaning up construction sites.
- Avoid handling or disturbing loose material that contains asbestos.
- Never use compressed air for cleaning. Also avoid using leaf blowers.
- Avoid dry sweeping, shoveling, or other dry clean-up methods.
- When drilling rock, apply water through the drill stem to reduce airborne dust, or use a drill with a dust collection system.
- Follow OSHA and EPA standards for disposing of waste and debris that contains asbestos. Use appropriate leak-proof containers.
- Do not eat, drink, or smoke in dusty work areas where asbestos fibers may be airborne. Move away from the work area for breaks. Also wash your hands and face before eating, drinking, or smoking.
- Limit bystander exposure. Prevent visitors and coworkers from standing in work areas where asbestos fibers may be airborne.
- Use disposable protective clothing or clothing that is left in the workplace.
- Shower (if possible), wash your hair, and change out of work clothes before leaving the worksite. This helps prevent contamination of car, home, and other work areas.
- Do not wash work clothing at home. The people you live with could develop asbestos-related diseases from the fibers brought home on work clothes and boots.
- Drive slowly over unpaved roads, with windows and vents closed.
- Keep vehicles dust-free to prevent continuing exposure. Wash equipment and vehicles when the job is finished

Personal Protective Equipment (PPE)

When working with material that may contain asbestos, use proper breathing protection. When you need to reduce asbestos exposure below OSHA standards, wear respirators that use high-efficiency filters (e.g., N100). Supplied air respirators also are effective.

Which type of respirator to use depends upon the amount of airborne asbestos or conditions of use. Medical clearance and respirator training are also required. Disposable respirators or dust masks do not prevent asbestos exposure. If personal protective equipment (PPE) is required at your worksite for asbestos work, then use proper respiratory protection. OSHA guidelines for PPE are posted at:

http://www.osha.gov/SLTC/respiratoryprotection/index.html or http://www.cdc.gov/niosh/npptl/topics/respirators/

How can asbestos make you sick?

Asbestos exposure and health

If asbestos fibers are in the air you breathe, the fibers may lodge in your lungs. The tiny fibers can scar your lungs and make it difficult to breath. That condition is called asbestosis. The fibers also can cause lung cancer and mesothelioma. Mesothelioma is a cancer of the membrane that covers the lungs and chest cavity (pleura). It is also a cancer of the membrane that lines the abdominal cavity (peritoneum). The symptoms of these diseases do not usually appear until about 15 to 40 years after the first exposure to asbestos. However, being exposed to asbestos does not mean you will definitely develop health problems. Many factors influence a person's chances of developing disease. They include how much, how often, and how long a person is exposed to asbestos. They also include the type of asbestos the person is exposed to, and that person's smoking history.

Workers who have significant past or ongoing exposure to asbestos should get a medical exam from a physician who knows about diseases caused by asbestos. The OSHA asbestos standard (http://www.osha.gov/SLTC/asbestos/compliance.html) describes medical tests used to assess workers exposed to asbestos.

For more information about asbestos-related disease, refer to ATSDR's "Asbestos and Health: Frequently Asked Questions" fact sheet. You can find it online at: http://www.atsdr.cdc.gov/NOA/Asbestos-and%20Health.pdf

Smoking and asbestos exposure

Smokers exposed to asbestos are much more likely to develop asbestos-related lung cancer than are most nonsmokers. Smoking also causes asbestosis to progress more quickly. Workers should quit smoking and avoid the cigarette smoke of others. Employers can help workers by offering smoking cessation programs.

Where can you get more information?

Stay informed

Contact ATSDR or the National Institute for Occupational Safety and Health (NIOSH) for more information about how to limit exposure to asbestos in the workplace and for answers to specific questions.

Toll free call:

1-888-42-ATSDR (1-888-422-8737) ATSDR:
http://www.atsdr.cdc.gov/asbestos/

or

1-800-35-NIOSH (1-800-356-4674) NIOSH:
http://www.cdc.gov/niosh/topics/asbestos/

Online Resources:

Protect Your Family: Reduce Contamination at Home
DHHS (NIOSH) Publication No. 97-125 (1997)_
http://www.cdc.gov/niosh/thttext.html

Occupational Respiratory Disease Surveillance (ORDS)
NIOSH Topic Page about occupational respiratory disease medical screening and monitoring:
http://www.cdc.gov/niosh/topics/surveillance/ORDS/

Work Related Lung Disease Surveillance Report 2002
DHHS (NIOSH) Publication No. 2003-111 (2002)
http://www.cdc.gov/niosh/docs/2003-111/2003-111.html

Environmental Protection Agency:

Naturally Occurring Asbestos in California:
http://www.epa.gov/region09/toxic/noa/index.html

General Information about Asbestos:
http://www.epa.gov/oppt/asbestos/help.html

Some of the information in this fact sheet comes from the brochure NIOSH Recommendations for Limiting Potential Exposures of Workers to Asbestos Associated with Vermiculite from Libby, Montana 2002. Access online at http://www.cdc.gov/niosh/docs/2003-141/ or call 1-800-35-NIOSH to request a copy.