

# ATSDR Case Studies in Environmental Medicine Asbestos Toxicity



**U.S. Department of  
Health and Human Services**  
Agency for Toxic Substances  
and Disease Registry

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

CASE STUDIES IN ENVIRONMENTAL MEDICINE  
(CSEM)

# Asbestos Toxicity

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**Key Concepts**

- Although asbestos is no longer used in many products, it will remain a public health concern well into the 21st century.
- Intact asbestos sources in buildings release few fibers and should be left undisturbed. Damaged or crumbling materials should be repaired or removed only by certified asbestos-removal professionals.
- Asbestos exposure is associated with a type of pulmonary fibrosis (asbestosis), pleural abnormalities (localized and diffuse pleural thickening, rounded atelectasis), mesothelioma, and lung cancer, and it may be associated with cancer at some extra-thoracic sites.

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**About This and Other Case Studies in Environmental Medicine**

This educational case study document is one in a series of self-instructional modules designed to increase the primary care provider's knowledge of hazardous substances in the environment and to promote the adoption of medical practices that aid in the evaluation and care of potentially exposed patients. The complete series of Case Studies in Environmental Medicine is located on the ATSDR Web site at URL: <http://www.atsdr.cdc.gov/csem/csem.html> In addition, the [downloadable PDF](#) version of this educational series

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and other environmental medicine materials provides content in an electronic, printable format, especially for those who may lack adequate Internet service.

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Please Note: Each content expert for this case study has indicated that there is no conflict of interest that would bias the case study content.

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**U.S. Department of Health and Human Services**  
**Agency for Toxic Substances and Disease Registry**  
**Division of Toxicology and Human Health Sciences**  
**Environmental Medicine Branch**

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## How to Use This Course

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<b>Introduction</b>	The goal of <i>Case Studies in Environmental Medicine</i> (CSEM) is to increase the primary care provider's knowledge of hazardous substances in the environment and to help in evaluation and treating of potentially exposed patients. This CSEM focuses on asbestos toxicity.
<b>Availability</b>	Two versions of the Asbestos Toxicity CSEM are available. <ul style="list-style-type: none"><li>• The HTML version <a href="http://www.atsdr.cdc.gov/csem/csem.asp?csem=29&amp;po=0">http://www.atsdr.cdc.gov/csem/csem.asp?csem=29&amp;po=0</a> provides content through the Internet</li><li>• The downloadable PDF version <a href="http://www.atsdr.cdc.gov/csem/asbestos_2014/docs/asbestos.pdf">http://www.atsdr.cdc.gov/csem/asbestos_2014/docs/asbestos.pdf</a> provides content in an electronic, printable format, especially for those who may lack adequate Internet service.</li><li>• The HTML version offers interactive exercises and prescriptive feedback to the user.</li></ul>
<b>Instructions</b>	To make the most effective use of this course. <ul style="list-style-type: none"><li>• Take the Initial Check to assess your current knowledge about asbestos toxicity.</li><li>• Read the title, learning objectives, text, and key points in each section.</li><li>• Complete the progress check exercises at the end of each section and check your answers.</li><li>• Complete and submit your assessment and posttest response online if you wish to obtain continuing education credit. Continuing education certificates can be printed immediately upon completion.</li></ul>

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**Instructional Format**

This course is designed to help you learn efficiently. Topics are clearly labeled so that you can skip sections or quickly scan sections you are already familiar with. This labeling will also allow you to use this training material as a handy reference. To help you identify and absorb important content quickly, each section is structured as follows:

<b>Section Element</b>	<b>Purpose</b>
Title	Serves as a “focus question” that you should be able to answer after completing the section.
Learning Objectives	Describes specific content addressed in each section and focuses your attention on important points.
Text	Provides the information you need to answer the focus question(s) and achieve the learning objectives.
Key Points	Highlights important issues and helps you review.
Progress Check Exercises	Enables you to test yourself to determine whether you have mastered the learning objectives.
Progress Check Answers	Provide feedback to ensure you understand the content and can locate information in the text.

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**Learning Objectives**

Upon completion of the Asbestos CSEM, you will be able to:

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**Content Area****Objectives**

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**Overview**

- Explain what asbestos is.
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<b>Where Is Asbestos Found?</b>	<ul style="list-style-type: none"> <li>• Identify where asbestos exists in the United States.</li> <li>• Describe how asbestos is released into the air.</li> </ul>
<b>Exposure Pathways</b>	<ul style="list-style-type: none"> <li>• Identify the most important route of exposure to asbestos which leads to health effects.</li> </ul>
<b>Who Is at Risk</b>	<ul style="list-style-type: none"> <li>• Name the populations most heavily exposed to asbestos.</li> <li>• Describe who is at risk of domestic exposure to asbestos.</li> </ul>
<b>Standards and Regulations</b>	<ul style="list-style-type: none"> <li>• Explain the Occupational Safety and Health Administration's permissible exposure level for asbestos.</li> <li>• Explain the U.S. Environmental Protection Agency's maximum contaminant level for asbestos in drinking water.</li> </ul>
<b>Biological Fate</b>	<ul style="list-style-type: none"> <li>• Identify where asbestos fibers are most likely to be retained in the body.</li> </ul>
<b>Pathogenic Changes</b>	<ul style="list-style-type: none"> <li>• Describe the hypothesis behind the mechanisms scientists currently believe leads asbestos to induce pathogenic changes in the lungs.</li> </ul>
<b>Respiratory Effects</b>	<ul style="list-style-type: none"> <li>• Describe the most common respiratory conditions associated with asbestos.</li> </ul>
<b>Other Health Conditions</b>	<ul style="list-style-type: none"> <li>• Identify non-respiratory conditions that might be associated with exposure to asbestos.</li> </ul>
<b>Clinical Assessment</b>	<ul style="list-style-type: none"> <li>• Identify the primary focuses of the patient's exposure history (exposure and medical).</li> <li>• Describe the most typical findings on examination of asbestosis patients.</li> </ul>
<b>Clinical Assessment- Tests</b>	<ul style="list-style-type: none"> <li>• Describe chest radiograph findings associated with other asbestos-associated diseases.</li> <li>• Describe pulmonary function test findings associated with asbestosis.</li> </ul>
<b>Treatment and Management</b>	<ul style="list-style-type: none"> <li>• Identify two primary strategies for managing asbestos-associated diseases.</li> </ul>

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- Describe specific strategies for managing asbestosis.
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**Patient Education and Counseling**

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- List four instructions for patient self care.
  - Identify two instructions for clinical follow-up.
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## Initial Check

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**Instructions**

This Initial Check will help you assess your current knowledge and skill level about asbestos toxicity. To take the Initial Check, read the case below, answer the questions that follow, and then compare your answers with the answers provided.

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**Case**

A 66-year-old retired male presents with dyspnea on exertion. He first noticed the shortness of breath several months ago but was not concerned because it seemed so minor; he attributed it to aging. During the past few months, however, the dyspnea on exertion has gradually worsened. The patient has no other symptoms of respiratory or cardiac disease. His medical history is unremarkable except for

- An old back injury (compression fracture of L4) sustained while working as an electrician at a local shipbuilding facility and
- A 25 pack-year history of smoking, though the patient quit smoking 5 years ago.

On physical examination, the patient is in no apparent distress. Auscultation reveals bibasilar end-inspiratory rales. There are no signs of cyanosis, no clubbing of the fingers, and no peripheral edema. Heart sounds are normal, as are the results of the rest of the physical examination.

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**Questions**

1. What further workup is required for this patient?
  2. The exposure history indicates a 15-year history of exposure to asbestos at the shipyard, beginning 35 years ago and ending 20 years ago. The patient does not know the exposure levels but notes that
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he used a respirator during the last 5 years at the shipyard. In addition, when he was 21 years old, he swept floors at a vermiculite handling facility for a summer. He notes that the vermiculite plant was extremely dusty, but he was told it was just "nuisance dust."

Are the patient's symptoms likely to be related to asbestos exposure? Why or why not?

3. On a conventional chest radiograph, the radiologist (a certified "B Reader") finds small, irregular opacities in both lung bases consistent with early-stage asbestosis. The pulmonary function tests reveal a mostly restrictive pattern of deficits, with decreased carbon monoxide diffusing capacity (DLco). You refer the patient to a pulmonologist. The pulmonologist diagnoses asbestosis on the basis of the patient's exposure history, latency of symptoms (occurring 45 years after first exposure), chest radiograph findings, and pulmonary function results.

How will you manage the patient's condition?

4. Is the patient at risk for other asbestos-associated diseases? Why or why not?
5. Are the patient's family members at risk for asbestos-associated disease as a result of their association with the patient and his work with asbestos?
6. The patient has been married for 46 years and has four children. He notes that his wife laundered all his clothes from work, including his clothes from the summer job at the vermiculite plant and those from his job at the shipbuilding facility. His children had only incidental exposure from hugging him after work. The patient's wife, a two-pack-a-day smoker, has recently lost weight and developed sharp pains in her lower chest.

Could the wife's recent weight loss and chest pain be related to her husband's occupational exposure

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to asbestos? What work-up would you suggest for the patient's wife?

7. The patient asks if his children are at risk of asbestos-associated disease. How do you answer?

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**Initial Check  
Answers**

1. The exertional dyspnea and bibasilar end-inspiratory rales are suggestive of some type of interstitial pneumonitis. Because of the patient's history of work at a shipbuilding facility, a detailed exposure history is warranted. You should ask the patient about

- Possible exposures (especially to asbestos) at the shipbuilding facility.
- Other jobs at which the patient may have been exposed directly or indirectly to asbestos.
- The source, intensity, frequency, and duration of any exposures.
- The time elapsed since first exposure.
- Any workplace dust measurements or cumulative fiber exposure.
- Use of personal protective equipment.
- Other sources of exposure, including paraoccupational exposures to or from members of the patient's household.
- Sources of environmental exposure, such as a residence near exposed asbestos-bearing rock or hobbies or recreational activities that involve materials contaminated with asbestos (e.g., home repairs or auto maintenance).

In addition to taking a detailed exposure history, it is prudent to order a chest radiograph and pulmonary function tests.

*The information for this answer comes from the "How Should Patients Exposed to Asbestos Be Evaluated?" section.*

2. Yes, the patient's condition is likely to be related to asbestos exposure. Diagnoses to consider include

- Asbestosis,
-

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- Idiopathic pulmonary fibrosis,
  - Other pneumoconiosis,
  - Hypersensitivity pneumonitis, and
  - Sarcoidosis and other interstitial pulmonary diseases.

Several aspects of the patient's case point to asbestosis as a likely diagnosis.

- History of exposure to asbestos in the shipbuilding facility and Libby vermiculite handling plant.
- Onset of symptoms many years after the exposures (consistent with a long latency period).
- Insidious onset of dyspnea on exertion.
- Bibasilar end-inspiratory rales.

The results of the chest radiograph (which should be read by a certified "B Reader") and pulmonary function tests will help with the differential diagnosis.

*The information for this answer comes from the "How Should Patients Exposed to Asbestos Be Evaluated?" section.*

3. To manage this patient's condition, you will
    - Advise the patient to avoid any further exposure to asbestos, tobacco smoke, and other respiratory irritants as practical;
    - Provide pneumococcal and annual influenza vaccines;
    - Advise the patient to contact you at any sign of chest infection;
    - Aggressively treat any chest infections that develop in the patient;
    - Advise the patient to contact you at any sign of other health changes, particularly changes that might be early signs of a malignancy (e.g., hoarseness, change in cough, coughing up blood, sores in the mouth, blood in stool);
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- 
- Arrange for colon cancer screening in accordance with current guidelines;
  - Schedule regular follow-up visits to monitor progression of the asbestosis and possible development of other asbestos-associated diseases;
  - Document any impairments related to work-related asbestos exposure; and
  - Notify the patient that he has an occupational disease and arrange for appropriate follow-up. Refer the patient to an occupational specialist who can explain all the treatment, legal (such as workman compensation) and employment ramifications of a work-related pulmonary disease.

*The information for this answer comes from the "How Should Patients Exposed to Asbestos Be Treated and Managed?" section.*

4. Yes, the patient is at risk of other asbestos-associated diseases. The patient's past exposures to asbestos were significant enough to have led to the development of asbestosis. These exposures can also lead to the development of other asbestos-associated diseases such as asbestos-related pleural abnormalities, lung carcinoma, and pleural or peritoneal mesothelioma. Additionally, the patient was previously a smoker and the effects of smoking and asbestos exposure are synergistic with respect to lung cancer (i.e., patients with a history of both smoking and asbestos exposure face a risk greater than what would be expected if the individual effects of each of these two risk factors were simply summed).

*The information for this answer comes from the "What Other Health Conditions Are Associated with Asbestos?" section.*

5. Possibly. While taking the patient's exposure history, it is important to ask about possible paraoccupational as well as environmental
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exposures to members of the patient's household. These can include inhalation of asbestos fibers from

- The worker's skin, hair, and clothing (depending on PPE and post work showering was not used);
- Air and dust from nearby vermiculite- or asbestos-handling facilities;
- Air and dust from nearby mining operations or other blasting/disruption of asbestos-bearing rock; and
- Outdoor recreation in areas of exposed asbestos-bearing rock.

You should also ask about other possible exposure sources such as

- Materials used for hobbies and recreation.
- Outdoor activities that could involve exposure to exposed asbestos-bearing rock, particularly if the patient lives near a geologic source.
- Vermiculite attic insulation contaminated with asbestos.

All of these types of exposures could place family members and other household contacts at risk of asbestos-associated disease.

*The information for this answer comes from section the "Who Is At Risk of Exposure to Asbestos?" section.*

6. Yes, the wife's symptoms could be related to her husband's occupational exposures to asbestos. Given that she laundered her husband's work clothes when he had two jobs involving asbestos, she could have received significant paraoccupational exposures to asbestos. To determine whether these exposures led to an asbestos-associated disease, you recommend that the patient's wife:

- Come in for an office visit,
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- 
- Have a chest radiograph, and
  - Undergo pulmonary function tests.

The wife's chest radiograph shows a pleural thickening associated with a slight pleural effusion on the lower right lung field. You refer the wife to a pulmonologist, who orders a computed tomography (CT) scan and performs a pleural biopsy. The pulmonologist diagnoses pleural mesothelioma, refers her to a cancer center, and provides the family with a referral for psychosocial support.

*The information for this answer comes from section the "How Should Patients Exposed to Asbestos Be Evaluated?" section.*

7. You explain that the risk of asbestos-associated diseases is generally related to dose (duration times level of exposure, or cumulative exposure) such that the most heavily exposed individuals are most likely to become diseased. The children received paraoccupational exposure to asbestos from dust and residue carried home on their father's skin and clothing, so their risk of asbestos-associated disease is less than his occupational risk but more than the background risk of the general population. You note that asbestos-associated disease, particularly mesothelioma, can occur with paraoccupational exposure and there is an extremely low risk of mesothelioma with the background exposures to asbestos experienced by people in the general population.

*The information for this answer comes from the "What Respiratory Conditions Are Associated with Asbestos?" section.*

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## What Is Asbestos

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### Learning Objectives

- Upon completion of this section, you will be able to
- Explain what asbestos is.
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**Introduction**

During much of the past century, asbestos was widely used for industrial and construction applications. In the 1970s, following enactment of various laws that established Federal agencies such as the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) with missions to protect the environment, the general public, workers, and consumers, some uses of asbestos began to be banned or otherwise regulated. This was due to growing scientific evidence concerning the association of asbestos with serious health effects. For example, in 1973 the EPA banned the use of spray-on building insulation and fireproofing containing more than 1 percent asbestos under authority of the Clean Air Act [EPA 2013] <https://www.epa.gov/asbestos/asbestos-laws-and-regulations>

As a result of research showing a clear link between asbestos exposure and various serious diseases, increasing regulation of asbestos, and high burdens of corporate liability due to asbestos, asbestos mining in the United States ceased in 2002 and the commercial use of imported asbestos in the United States has declined dramatically since the late 1970s. However, asbestos is still in use in some products today and asbestos remains in many older buildings [NIOSH 2011a].

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**Definition**

Asbestos is the generic name given to a commercially and legally defined group of six naturally occurring fibrous silicate minerals that have been widely used in commercial products. Asbestos is composed of silicate chains bonded with magnesium, iron, calcium, aluminum, and sodium or trace elements to form long, thin, separable fibrils. These fibrils are arranged in parallel and a single microscopically-observed asbestos fiber can represent multiple fibrils that have not separated.

Currently, there are varying regulatory and scientific definitions applied to “asbestiform” and “nonasbestiform” minerals that give origin to elongated particles of known or potential health concern. Many of these minerals are not included in the legal definition of asbestos and are not regulated. There exists a need for research to identify the specific characteristics of elongated mineral particles that determine their relative toxicities so that exposures can be appropriately managed to prevent associated health effects [NIOSH 2011a].

Asbestos occurs naturally, but much of its current presence in the environment stems from mining and commercial uses.

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**Classes**

Asbestos fibers are classified by mineral structure as serpentine or amphibole.

<b>Table 1. Types of Asbestos</b>	
<b>Serpentine</b>	<b>Amphibole</b>



Figure 1. Photo of serpentine asbestos

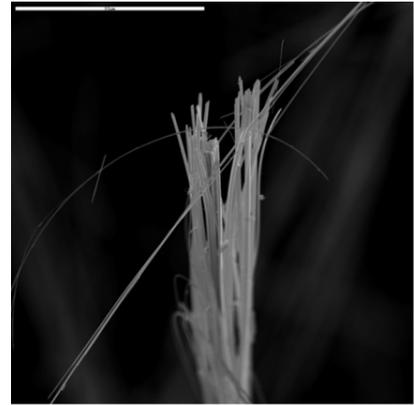


Figure 2. Photo of amphibole asbestos

Long, flexible fibers

Brittle with a rod or needle shape

Member: chrysotile

Members: crocidolite, amosite, anthophyllite, tremolite, actinolite

Currently accounts for 99% of world's commercial, purposeful use of asbestos [NIOSH 2011a]

Currently, accounts for 1% of commercial, purposeful use of asbestos [NIOSH 2011a]

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**Properties**

Asbestos was widely used commercially because of its

- High tensile strength
- Resistance to acids and alkalis
- Resistance to heat and flame
- Flexibility.

These properties make asbestos commercially useful but also stable in the environment. Once released to the environment, asbestos tends to persist.

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**Key Points**

- Asbestos is a group of fibrous silicate minerals.
- There are two classes of asbestos: serpentine and amphibole.
- Asbestos is now used much less widely in the United States and many other countries than in the past.
- Asbestos is stable and persists in the environment.

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**Progress Check**

1. Asbestos is a
  - A. Group of fibrous mineral silicates.
  - B. Naturally occurring substance.
  - C. Commercially used substance.
  - D. All of the above.

*To review relevant content, see "Definition" in this section.*

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**Where Is Asbestos Found?**

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**Learning Objectives**

Upon completion of this section, you will be able to

- Identify where asbestos exists in the United States and
  - Describe how asbestos is released into the air.
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**Introduction**

Asbestos was widely used in the United States until health concerns led to some uses being banned and some voluntary phase outs [Seidman and Selikoff 1990]. Since the early 1970s, use of asbestos has declined substantially; mining of asbestos ceased in the United States in 2002, though some asbestos continues to be imported [NIOSH 2011a].

Asbestos is still used in some construction materials. Some previously marketed asbestos-containing products, such as amphibole-contaminated vermiculite insulation, remain in many homes and other buildings in the United States. Asbestos fibers are released into the air when friable asbestos-containing materials are disturbed. In addition to being at risk for potential exposure from degradation of asbestos-containing commercial products, people in some areas of the world may be at risk because of geological deposits of asbestos at or near the earth's surface, which can release asbestos by natural weathering or man-made disturbance. Such deposits are often referred to as "naturally occurring asbestos."

For more information on the subject of naturally occurring asbestos and maps showing the locations of naturally occurring asbestos:

ATSDR website –

<https://www.atsdr.cdc.gov/PHS/PHS.asp?id=28&tid=4>

United States Geological Services website –

<https://www2.usgs.gov/envirohealth/geohealth/images/GreaterThanBenchmarksMap.png>

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**Current Commercial Uses**

Today, asbestos used in the United States is imported. Recent uses of asbestos in the United States include

- Automobile clutches,
  - Brake pads,
  - Corrugated sheeting,
  - Imported cement pipe,
  - Roofing materials, and
  - Vinyl tile [American Thoracic Society 2004].
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**Former Commercial Uses**

Until the 1970s, asbestos was widely used in the construction, shipbuilding, and automotive industries, among others. For example, asbestos was formerly used in some of the following items:

- Boilers and heating vessels,
- Cement pipe,
- Clutch, brake, and transmission components,
- Conduits for electrical wire,
- Corrosive chemical containers,
- Electric motor components,
- Heat-protective pads,
- Laboratory furniture,
- Paper products,
- Pipe covering,
- Roofing products,
- Sealants and coatings,
- Insulation products, and
- Textiles (including curtains).

These materials remain in many buildings, ships, and automobiles built before 1975 [Seidman and Selikoff 1990].

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**Contaminated Commercial Products**

Asbestos has been a contaminant in other products such as

- Vermiculite in potting soil and
- Vermiculite home insulation.

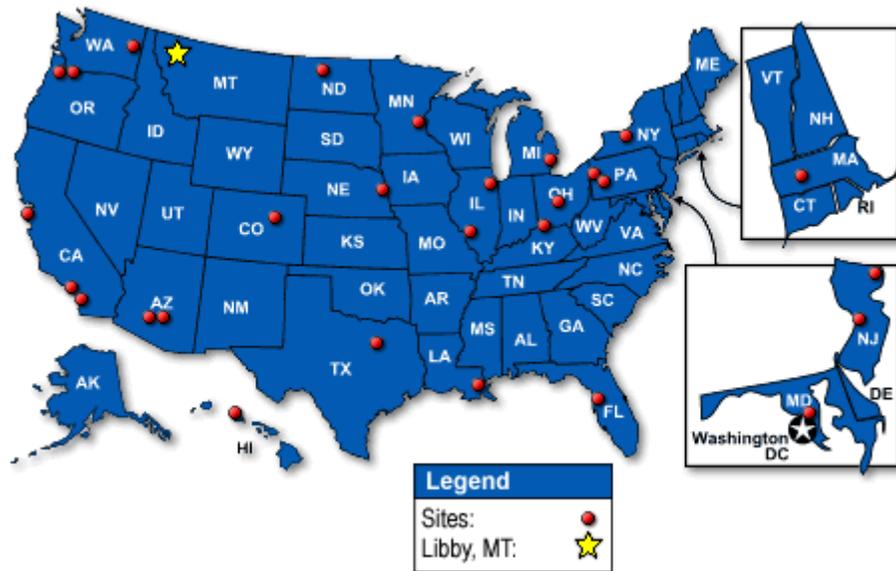
Vermiculite contaminated with asbestos was produced as late as 1990 from a mine near Libby, Montana. The mined vermiculite ore contained amphibole asbestos. It was processed at 245 sites around the country, and contaminated vermiculite products were distributed nationally [ATSDR 2001a]. See below for a map with a sample of 30 out of the 245 sites where Libby vermiculite was processed nationwide.

Although all vermiculite currently used in potting soil is essentially amphibole-free, pre-1990 products from the Libby mine contain amphibole asbestos. Many homes still have this vermiculite insulation in their attics.

For more information on amphibole asbestos and vermiculite insulation, please refer to the ATSDR website on asbestos at

<https://www.atsdr.cdc.gov/PHS/PHS.asp?id=28&tid=4>

Figure 3. Map of 28 ATSDR priority sites out of 245 Libby vermiculite mining and processing sites



### 28 ATSDR priority sites

- Beltsville, MD
- Dallas, TX
- Dearborn, MI
- Denver, CO
- Easthampton, MA
- Edgewater, NJ
- Ellwood City, PA
- Glendale, AZ
- Hamilton Township, NJ
- Honolulu, HI
- Libby, MT
- Los Angeles, CA
- Marysville, OH
- Minneapolis, MN
- Minot, ND
- New Castle, PA
- New Orleans, LA
- Newark, CA
- Omaha, NE
- Phoenix, AZ
- Portland, OR (N. Harding)
- Portland, OR (N. Suttle)
- Santa Ana, CA
- Spokane, WA
- St. Louis, MO
- Tampa, FL
- Trenton, NJ
- Weedsport, NY
- West Chicago, IL
- Wilder, KY

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**Homes and Buildings**

Besides homes that contain vermiculite insulation, asbestos in friable (easily pulverized or crumbled) construction materials is also a concern. Asbestos embedded in solid materials (such as wallboards) is less easily disturbed and therefore less likely to be released into the air unless it is cut, drilled, or sanded.

Many construction materials produced before 1975 contained asbestos including (but not limited to)

- Caulking and joint compound,
- Ceiling and floor tiles,
- Heat resistant fabrics, and
- Insulation used to cover furnaces and hot water and steam pipes,
- Roofing shingles,
- Siding shingles,
- Textured paints and patching compounds used on wall and ceilings,
- Walls and floors used with wood burning stoves [EPA 2012a].

These sources of asbestos can be disturbed during home redecoration, renovation, and demolition. Asbestos can also be released during destruction of housing stock during natural or technological (human-made) disasters.

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**The Natural Environment**

As a result of human use, asbestos fibers are now widely dispersed in the environment. Background levels in the air are extremely low, about 0.0001 fibers/cc [Holland and Smith 2003].

Asbestos is also present in the environment naturally, primarily in underground rock.

- In most areas asbestos fibers are not released into the air because the rock is too deep to be disturbed easily.
- In some areas, such as parts of California, Virginia, and New Jersey (and across the globe in Turkey and Corsica) where asbestos-bearing rock is close enough to the surface that construction and other human activities can disturb it, high concentrations of asbestos fibers can be released into the air [ATSDR 2001a; Constantolopoulos 2008; Hasanoglu et al. 2003; Luo et al. 2003].

There can be clusters of cases of a rare asbestos-related cancer, mesothelioma in places where high exposures to naturally occurring asbestos occurs.

- A recent ecological study found an elevated risk for mesothelioma occurrence in an area in New Caledonia where roads are covered in local rock that contains asbestos [Baumann et al. 2011].
- Another ecological study in California found a relationship between proximity to geologic sources of naturally occurring asbestos and incidence of malignant mesothelioma [Pan X et al. 2005].

**Table 2. Examples of Sources of Asbestos in the Environment.**

<b>Source of Asbestos</b>	<b>Location in the Environment</b>
Mining, milling, and weathering of asbestos-bearing rock	Outdoor air and settled dust

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Release of fibers from disturbed building materials ( <i>e.g.</i> , vermiculite insulation)	Indoor air
Manufacture, wear, and disposal of asbestos-containing products	Outdoor and indoor air and settled dust
Release of fibers from brake linings or crushed asbestos-containing rock used in road construction	Street dust
Erosion of natural land sources, discarded mine and mill tailings, asbestos cement pipe, disintegration of other asbestos-containing materials transported by rainwater [EPA 2012b]	Drinking water

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### Key Points

- Until the 1970s, asbestos was widely used in the construction, shipbuilding, and automotive industries.
  - Asbestos-contaminated vermiculite products were produced until 1990.
  - Some home insulation and other building materials produced before 1990 contain asbestos.
  - Asbestos fibers are mainly released into the air when asbestos-containing materials are disturbed.
  - In a few areas, asbestos-bearing rock close to the earth's surface can be disturbed and release high concentrations of asbestos fibers into the air.
-

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**Progress  
Check**

2. Asbestos currently in the environment comes from
  - A. Current production of commercial products and building materials.
  - B. Past production of commercial products and building materials.
  - C. Natural release of asbestos fibers from weathered rock.
  - D. All of the above.

*To review relevant content, see "The Natural Environment" in this section.*

3. Asbestos fibers are released into the air mainly when
  - A. Asbestos-containing materials are loose, crumbling, or disturbed.
  - B. Asbestos is fixed in solid materials such as wallboard.
  - C. Asbestos-bearing rock lays unexposed deep underground.
  - D. All of the above.

*To review relevant content, see "Introduction" in this section.*

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## **How Are People Exposed to Asbestos?**

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**Learning  
Objectives**

- Upon completion of this section, you will be able to
- Identify the most important route of exposure to asbestos which leads to health effects.
-

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**Introduction**

Exposure to asbestos can occur when asbestos-containing material (man-made or natural) is disturbed releasing asbestos fibers into the air. Asbestos that is embedded or contained in undisturbed solid materials presents a negligible risk of exposure.

The primary route of asbestos entry into the body is inhalation of air that contains asbestos fibers. Asbestos can also enter the body via ingestion. With dermal exposure, asbestos fibers may lodge in the skin.

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**Inhalation**

The air pathway is the most important route of exposure to asbestos. It is the route that most commonly leads to illness. Exposure scenarios include inhalation of air that is contaminated:

- During work with asbestos,
- During work in the same space as others working with asbestos,
- From a worker's skin, hair, and clothing,
- In areas surrounding a mining operation,
- In areas of the world where natural weathering, landscaping, construction, or other human activity (such as gardening and outdoor recreation) results in disturbance of asbestos-bearing rock, and
- In homes and buildings where renovations or demolitions disturb asbestos-containing building materials.

The first four scenarios above were common until the 1970s, when the U.S. Environmental Protection Agency (EPA) began to regulate the industrial uses of asbestos and the Occupational Safety Health Administration (OSHA) developed workplace exposure standards [Seidman and Selikoff 1990]. Today, the last two scenarios are the more common because of declining use of asbestos in developed countries [British Thoracic Society 2001; NIOSH 2011a].

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<b>Ingestion</b>	<p>Ingestion—a less important pathway of exposure—occurs through</p> <ul style="list-style-type: none"> <li>• Swallowing material removed from the lungs via mucociliary clearance in persons who have inhaled asbestos fibers into the lungs [NIOSH 2011b]</li> <li>• Drinking water contaminated with asbestos (for example, from erosion of natural land sources, discarded mine and mill tailings, asbestos cement pipe, or disintegration of other asbestos-containing materials transported by rainwater).</li> <li>• Eating biota, such as clams, that are contaminated with asbestos [ATSDR 2013].</li> <li>• Incidental ingestion during swimming in contaminated water [ATSDR 2009].</li> </ul> <p>Asbestos levels in most water supplies are well below the EPA maximum contaminant level (MCL), so significant exposure by drinking water is uncommon.</p>
<b>Skin</b>	<p>Today, with the appropriate use of personal protective equipment by those working with asbestos, dermal contact is rarely a significant exposure pathway. In the past, handling asbestos could result in significant dermal contact and exposure. Asbestos fibers could become lodged in the skin, producing a callus or corn, but not more serious health effects.</p>
<b>Key Points</b>	<ul style="list-style-type: none"> <li>• The air pathway (inhalation of contaminated air) is the most important route of exposure to asbestos and the route that most commonly leads to illness.</li> <li>• Ingestion is a less common exposure pathway, but exposure can occur after swallowing of material cleared from the lungs.</li> <li>• Significant dermal contact is unusual, but it can lead to calluses or corns.</li> </ul>
<b>Progress Check</b>	<p>4. The most important route of exposure to asbestos is</p> <ol style="list-style-type: none"> <li>1. Inhalation.</li> <li>2. Ingestion.</li> <li>3. Dermal contact.</li> </ol>

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4. All are equally important.

*To review relevant content, see “Inhalation” in this section.*

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## **Who Is at Risk of Exposure to Asbestos?**

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### **Learning Objectives**

Upon completion of this section, you will be able to

- Name the populations most heavily exposed to asbestos and
- Describe who is at risk of domestic exposure to asbestos.

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### **Introduction**

In the past, asbestos exposure was associated mainly with mining and milling of the raw material and with workers engaged in construction and product manufacture or use of end products. In the industrialized west, these heavy asbestos exposures peaked during the 1960s and 1970s and then declined as worker protection regulations were put in place and later as industrial use of asbestos decreased [NIOSH 2011a].

Because of long latency periods (10–40 years), workers exposed to asbestos in the 1960s and 1970s are now manifesting asbestos-associated diseases. Indeed, the mortality of asbestosis has increased from the 1960s to 2000. The National Institute of Occupational Safety and Health (NIOSH) data indicates that asbestosis deaths increased substantially from the 1960s to the 2000s; they are expected to continue occurring for decades [NIOSH 2011a; CDC 2004; Antao et al. 2009].

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National statistics that illustrate this trend are available at

<http://www2a.cdc.gov/drds/WorldReportData/FigureTableDetails.asp?FigureTableID=2567&GroupRefNumber=F01-01>

Today in the United States, most occupational exposures occur during

- Repair,
- Renovation,
- Removal, or
- Maintenance

of asbestos-containing products installed years ago. The Occupational Safety and Health Administration (OSHA) has estimated that 1.3 million employees in construction and general industry are exposed to asbestos on the job during these above-mentioned activities [NIOSH 2011a].

People can also be exposed at home, both to old sources of asbestos as a result of activities such as home renovation or to new sources of asbestos as a result of certain types of recreational activities and hobbies such as auto repairs and, in areas of naturally occurring asbestos in local soils, gardening.

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**Past Direct Occupational Exposures**

In the past, many occupations entailed exposures to asbestos (see table below). Studies have documented the scale of the problem.

- In the United States, an estimated 27 million workers were exposed to aerosolized asbestos fibers between 1940 and 1979 [Nicholson et al. 1982]. These past exposures were heavier than what workers face today. According to NIOSH, current worker exposures exceeding the NIOSH recommended exposure limit (REL) declined from 6.3% of workers in 1987–1994 to 4.3% in 2000–2003 [NIOSH 2011a].

<b>Table 3. Occupational Exposure to Asbestos</b>	
<b>Occupations</b>	<b>Businesses</b>

<ul style="list-style-type: none"> <li>• Auto mechanics</li> <li>• Boilermakers</li> <li>• Bricklayers</li> <li>• Building inspectors</li> <li>• Carpenters</li> <li>• Demolition workers</li> <li>• Drywallers</li> <li>• Electricians</li> <li>• Floor covering workers</li> <li>• Furnace workers</li> <li>• Glaziers</li> <li>• Grinders</li> <li>• Hod carriers</li> <li>• Insulators</li> <li>• Ironworkers</li> <li>• Laborers</li> <li>• Libby vermiculite exfoliation plant workers</li> <li>• Longshoremen</li> <li>• Maintenance workers</li> <li>• Merchant marines</li> <li>• Millwrights</li> <li>• Operating engineers</li> <li>• Painters</li> <li>• Pipefitters</li> <li>• Plasterers</li> <li>• Plumbers</li> <li>• Roofers</li> <li>• Refinery workers</li> <li>• Sheet metal workers</li> <li>• Shipyard workers</li> <li>• Steamfitters</li> <li>• Tile setters</li> <li>• U.S. Navy personnel</li> <li>• Welders</li> </ul>	<ul style="list-style-type: none"> <li>• Asbestos product manufacturing (insulation, roofing, building materials)</li> <li>• Automotive repair shops (especially those that involve repair of brakes, clutches)</li> <li>• Construction companies</li> <li>• Maritime companies</li> <li>• Mining companies</li> <li>• Offshore rust removal businesses</li> <li>• Oil refineries</li> <li>• Power plants</li> <li>• Railroads</li> <li>• Manufacturers of sand or abrasives</li> <li>• Shipbuilders, ship lines, and shipyards</li> <li>• Steel manufacturers</li> <li>• Tile installation</li> </ul>
<p>* Source: NIOSH 2003; 2008</p>	

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**Past Secondary Occupational Exposure**

Secondary exposure occurred when people who did not work directly with asbestos were nevertheless exposed to fibers as a result of sharing workspace where others handled asbestos. For example, electricians who worked in shipyards were exposed because asbestos was used to coat the ships' pipes and hulls [Pan S et al. 2005].

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**Past Paraoccupational Exposures**

In the past, asbestos workers went home covered in asbestos dust because of a lack of proper industrial hygiene. The workers' families and other household contacts were then exposed via inhalation of asbestos dust:

- From workers' skin, hair, and clothing, and
- During laundering of contaminated work clothes.

A mortality study of 878 household contacts of asbestos workers revealed that 4 out of 115 total deaths were from pleural mesothelioma and that the rate of deaths from all types of cancer was doubled [Joubert et al. 1991]. Also, 11 cases of mesothelioma (6M:5F ratio) were diagnosed from 1995–2006 among individuals who had not worked at the vermiculite operations in Libby, Montana, but who had some other indirect association with those operations. Most had environmental exposure from living, working, or regularly shopping in Libby community; two were family members of vermiculite workers [Whitehouse et al. 2008].

In other environmental exposures [Constantopoulos 2008] asbestos was released into the air and soil around facilities such as

- Building demolitions,
- Factories handling asbestos,
- Power plants,
- Refineries,
- Shipyards,
- Steel mills, and
- Libby vermiculite mine.

People living around these facilities have been also exposed to asbestos through their residence close to asbestos-using industries.

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**Current Occupational Exposures**

Currently, the people most heavily exposed to asbestos in the United States are those in construction trades. This population includes an estimated 1.3 million construction workers as well as workers in building and equipment maintenance [American Thoracic Society 2004]. Because most asbestos was used in construction, and most asbestos produced is still used in this industry, risk to these workers can be considerable if the hazard is not recognized and Occupational Safety and Health Administration (OSHA) standards are not enforced.

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**Disaster-Related Exposures**

Responders to the World Trade Center (WTC) disaster were exposed on an acute short-term basis to an asbestos-containing mixture of particulate matter released by the collapsing towers and by rescue, recovery, and clean-up activities.

Among the early responders who were exposed short-term during the hours to days after the collapse were

- Firefighters,
- Police,
- Paramedics,
- Construction workers, and
- Volunteers [Landrigan et al. 2004].

Some people exposed acutely to the high concentrations of dust released by the towers collapse subsequently developed reactive airways dysfunction syndrome (RADS). The U.S. Environmental Protection Agency (EPA) found that exposure of laboratory mice to WTC PM<sub>2.5</sub> also developed airway irritation [EPA 2002].

Another population potentially exposed to the complex particulates from the tower collapse was the people whose residences in nearby buildings were contaminated with dust from the WTC collapse.

Public concern about possible health risks faced by this population led authorities to study the air quality and settled dust in residences near Ground Zero. EPA found asbestos fibers greater than 5 microns in length in 0.4% of settled dust samples (n=22,497) collected from these residences [EPA 2005]. At the time of residential air

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sampling for a study by the New York Department of Health and the Agency for Toxic Substances and Disease Registry (ATSDR) in November-December 2001 [New York City Department of Health and Mental Hygiene and ATSDR 2002] total fiber levels (i.e., including asbestos and all other fibers present) were orders of magnitude below the occupational exposure limit for asbestos, even with aggressive sampling. It was estimated, based on an extreme worst-case scenario, that someone living for a full year in an uncleaned residence would have a 1 in 10,000 risk of developing cancer (mesothelioma) due to that exposure [New York City Department of Health and Mental Hygiene and ATSDR 2002]. The same authorities concluded that, with appropriate cleaning of residences, the dust would present little risk.

Natural disasters can also release asbestos from both naturally occurring and man-made sources. An example of a natural disaster involving the release of naturally occurring asbestos is the Swift Creek landslide in Washington State. The rock in this very large, unstable slope contains naturally occurring asbestos. As it progressively breaks up over time, slumping and sliding into the valley below, it releases asbestos into the environment, leaving those nearby at risk of exposure [ATSDR 2008].

An example of a natural disaster releasing man-made asbestos would be a tornado that releases asbestos into the environment when it destroys asbestos-containing buildings.

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**Direct Domestic Exposures**

As noted previously, some Libby vermiculite home attic insulation produced before 1990 and many other home and building materials produced before asbestos was banned for fireproofing in 1975 contain asbestos.

- People who live in homes with these materials are at risk of exposure if the materials are loose, crumbling, and disturbed by household activities or renovations.
- In such cases, the asbestos materials should be removed or encapsulated by a trained and certified asbestos contractor.
- For information on where to find certified asbestos contractors in your state, homeowners should contact their local health department.

On the other hand, asbestos contained in intact solid material poses a negligible risk of exposure. Air levels of asbestos in a building with asbestos embedded in building materials and undisturbed average 0.0002 f/cc, nearly 3 orders of magnitude below OSHA's permissible exposure limit for occupational exposures [Holland and Smith 2003].

There are many ways that people can also be exposed to asbestos through hobbies and recreational activities that entail contact with materials containing asbestos; some examples are such activities as home renovation, auto repair, and urban spelunking. In places where naturally occurring asbestos is close to the earth's surface, activities such as gardening and dirt biking can cause exposures if asbestos-bearing rock is disturbed.

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<b>Exposures at School</b>	<p>Measurable asbestos levels in schools are usually 100 to 1,000 times below OSHA's permissible exposure limit of 0.1 fibers/cc of air for asbestos [Holland and Smith 2003]. However, ATSDR does not use occupational standards when considering the risks to health of the general population from asbestos in the general environment. A specific environmental health assessment process is used.</p> <p>Over time, public concern led to widespread removal and abatement programs. Some facilities have higher levels of airborne asbestos after removal than before, highlighting the importance of proper encapsulation or removal by contractors; for if this does not occur, the levels will be higher post remediation.</p> <p>Schools are required by EPA to conduct inspections for asbestos and to follow correct abatement procedures using the techniques recommended by EPA. For more information on how schools should handle asbestos under the Asbestos Hazard Emergency Response Act (AHERA), refer to the section in this case study on standards and regulations.</p>
<b>Background Exposures</b>	<p>No known truly unexposed group exists in the world. The cumulative risk of background exposures is probably minor, however, and these concentrations cannot be reduced [Hillerdal 1999]. Whenever feasible, any source of pollution that releases significant amounts of asbestos fibers should be eliminated, using proper equipment and techniques, as soon as it is discovered.</p>
<b>The Libby Vermiculite Example</b>	<p>Most vermiculite used today contains low or non-detectable levels of asbestos. However, the vermiculite mined in Libby from the 1920s to 1990 was contaminated with various fibrous amphiboles. The amphiboles were comprised of "elongated mineral particles identified as a mixture of asbestiform amphiboles, including winchite, richterite, and tremolite asbestos" [Virta 2013] and constituted 95% of the vermiculite used in the United States during that time. The vermiculite operations in Libby are a good example of the many ways people can be at risk of asbestos. In this example, mining of the asbestos- contaminated</p>

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vermiculite ore in Libby resulted in asbestos exposures to

- Vermiculite miners,
- Household contacts of miners and Libby vermiculite plant workers,
- Children playing in piles of vermiculite in the area,
- Workers who worked in vermiculite exfoliation plants and other vermiculite handling sites throughout the United States after it was shipped there from Libby,
- People who live in homes with vermiculite home insulation, and
- Vermiculite transportation routes.

This vermiculite was also used in potting soil, but the U.S. EPA concluded that consumers “face only a minimal health risk from occasionally using vermiculite products at home or in their gardens” [EPA 2000].

For more information about amphibole-contaminated vermiculite, see

- ATSDR summary report on 28 priority vermiculite exfoliating sites at [https://www.atsdr.cdc.gov/csem/asbestos\\_2014/images/figure3\\_USAmap.jpg](https://www.atsdr.cdc.gov/csem/asbestos_2014/images/figure3_USAmap.jpg)
- EPA fact sheet about how to recognize and avoid exposure to vermiculite insulation in homes at <http://www2.epa.gov/asbestos/protect-your-family-asbestos-contaminated-vermiculite-insulation>

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**Key Points**

- Today, the populations most heavily exposed to asbestos are those in construction trades.
  - In the past, pipe fitters, shipyard workers, military workers, automobile mechanics, and people in many other occupations were also exposed.
  - In the past, household contacts of asbestos workers were exposed to asbestos dust carried home on workers' skin and clothing.
  - People in homes and buildings with loose, crumbling, or disturbed asbestos materials can be exposed to asbestos.
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- During renovations or asbestos abatement, asbestos materials should be encapsulated or removed by trained and certified asbestos contractors.
  - Asbestos embedded in intact solid materials poses little risk of exposure as long as it remains intact and undisturbed.
  - Natural outcroppings of asbestos can lead to human exposure in a number of ways.
  - Natural and technological disasters can lead to asbestos exposure.

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**Progress Check** 5. In the past, occupations that entailed exposure to asbestos included which of the following?

- A. Construction workers, carpenters, sheet metal workers, and pipe-fitters.
- B. Utility workers, boiler-makers, and electricians.
- C. Shipyard workers and automobile mechanics.
- D. All of the above.

*To review relevant content, see "Past Direct Occupational Exposures" in this section.*

6. Of the following, who is most likely to be at risk from health effects from asbestos exposure?

- A. A child attending a school with asbestos-containing tile flooring.
- B. An adult who uses vermiculite potting soil while gardening.
- C. A person who resided with an asbestos worker in the 1940s.
- D. A family living in a home with intact, solid asbestos-containing materials.

*To review relevant content, see "Direct Domestic Exposure" and "Exposures at School" in this section.*

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## **What Are U.S. Standards and Regulations for Asbestos Levels?**

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**Learning Objectives**

Upon completion of this section, you will be able to

- Explain the Occupational Safety and Health Administration (OSHA) permissible exposure limit for asbestos and
- Explain the U.S. Environmental Protection Agency's (EPA) maximum contaminant level for asbestos in drinking water.

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**Introduction**

The earliest evidence of asbestos-associated disease in workers was found in the 1930s by British studies [Lee and Selikoff 1979]. We now know that the toxic effects of asbestos depend on the nature and extent of exposure, particularly on the:

- Concentration of asbestos fibers involved in the exposure,
- Duration of exposure,
- Frequency of exposure,
- Type of asbestos fibers involved in the exposure, and
- Dimensions and durability of the asbestos fibers.

The Center for Disease Control and Prevention/National Institute for Occupational Safety and Health (NIOSH) and OSHA began establishing standards for asbestos in the 1970s. U.S. regulatory agencies such as EPA and OSHA recognize six asbestos and asbestiform minerals, i.e.,

- Actinolite asbestos,
- Amosite asbestos,
- Anthophyllite asbestos,
- Chrysotile asbestos,
- Crocidolite, and
- Tremolite asbestos

as legally regulated forms of asbestos out of the group of asbestiform minerals.

Asbestiform minerals are defined as crystal aggregates displaying these characteristics: groups of separable,

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long, thin, strong, and flexible fibers arranged in parallel [ATSDR 2001a].

Currently there is discussion underway to include as regulated substances asbestiform minerals that may have similar health effects to the previously mentioned forms of asbestos. However, nothing has been finalized at this time [OSHA 1992; NIOSH 2011a].

Currently, there are standards for asbestos in

- Drinking water,
- Schools,
- Some consumer products, and
- Workplace air.

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**Occupational Standards**

In 1986, OSHA in Standard 29 CFR 1910.1001 established the current permissible exposure limit (PEL) for asbestos in the workplace: (0.1 fibers/cc of air as a time weighed average) [OSHA 2012]. PELs are allowable exposure levels in workplace air averaged over an 8-hour shift of a 40 hour workweek. There are also OSHA standards (29 CFR 1915.1001) for shipyards and construction (1926.1101).

Additionally, OSHA standards (1915.1001 and 1926.1101) requires employers of all workers whose work exposes them to asbestos above the PEL or excursion limit (1.0 f/cc over 30-minute period) to

- Provide training in the engineering controls, work practices, and proper use of personal protective equipment (PPE),
  - Train workers in safety before beginning work and annually,
  - Train workers regarding the health effects of asbestos exposure, and
  - Inform workers of the relationship between smoking, asbestos exposure and increased risk of lung cancer.
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In addition, OSHA requires employers of workers who are exposed to asbestos above the PEL and who are employed in certain asbestos industries to

- Provide and make sure of correct use of PPE (respirators, protective clothing like coveralls and goggles),
- To undergo medical surveillance in order to identify those with signs of asbestos-associated disease, remove them from further exposure,
- Comply with regulations requiring documentation for work-related injury claims, and
- Provide information to workers about where they can go for help to stop smoking.

Components of the required medical surveillance include

- Chest radiograph,
- Physical examination,
- Spirometric test, and
- Standard questionnaire.

Further information about OSHA requirements is available at

<http://www.osha.gov/SLTC/asbestos/standards.html>

For further information about protection guidelines, contact NIOSH via 1-800-CDC-INFO or via

<http://www.cdc.gov/niosh/contact/>

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**Environmental Standards**

ATSDR does not consider the use of OSHA's PEL for workplace exposures to be appropriate for environmentally exposed populations since residential and/or environmental exposures are 24 hours a day year round, much longer than the typical 8-hour day and 40-hour workweek exposures of workers. Children and the elderly, who are not typically exposed in the workplace, may be more susceptible to exposure.

EPA has established a maximum contaminant level (MCL) for asbestos in drinking water of 7 MFL (million fibers per liter > 10  $\mu$ m in length) in drinking water [EPA 2011]. Asbestos in drinking water comes from two main sources:

- 
1. Decay of water mains constructed of asbestos-containing cement, and
  2. Erosions of naturally occurring asbestos deposits into watersheds [EPA 2012a].

In addition, EPA has

- Banned spraying of asbestos in building interiors (for fireproofing and ceilings),
- Developed guidelines for proper treatment of in-place asbestos in old buildings,
- Recommended “no visible emissions” of asbestos,
- Regulated demolition of buildings with asbestos (NESHAP rules), and
- Regulated uses of asbestos in industrial products and construction.

More information on EPA rules and regulations regarding asbestos is available at

<http://www2.epa.gov/asbestos/asbestos-laws-and-regulations>

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**Schools**

The Asbestos Hazard Emergency Response Act of 1982 (CFR 40, Part 763, Subpart E) requires that local education agencies

- Inspect schools for asbestos-containing material using certified inspectors,
- Analyze these materials for asbestos content,
- Post results and notify parents and employees if asbestos is found,
- Test air levels following clean-up,
- Develop appropriate management plans,
- Communicate openly about any asbestos abatement needed, and
- Maintain appropriate records [EPA 2012c].

EPA also warned school authorities that power buffing and power stripping of asbestos-tile floors in schools produces significant airborne asbestos levels. Floor maintenance must be performed by hand to prevent release of asbestos fibers.

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**Key Points**

- OSHA's PEL for asbestos in the workplace is 0.1 fibers/cc of air (8-hour TWA).
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- OSHA requires all asbestos-exposed workers to be trained in PPE; they must undergo medical surveillance if exposed above the PEL.
  - EPA's MCL for asbestos in drinking water is 7 MFL greater than 10um in length (million fibers per liter) of drinking water.
  - Local education agencies must inspect schools and analyze friable material for asbestos content, communicate results, and maintain records.
- 

**Progress Check** 7. OSHA's PEL for asbestos in the workplace is

- A. 10 fibers/cc of air (8-hour TWA).
- B. 1 fiber/cc of air (8-hour TWA).
- C. 0.1 fibers/cc of air (8-hour TWA).
- D. 0.01 fibers/cc of air (8-hour TWA).

*To review relevant content, see "Occupational Standards" in this section.*

8. EPA's MCL for asbestos in drinking water is

- A. 0.07 fibers per liter of drinking water.
- B. 7 million fibers per liter of drinking water.
- C. 700 fibers per liter of drinking water.
- D. 70,000 fibers per liter of drinking water.

*To review relevant content, see "Environmental Standards" in this section.*

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## What Is the Biological Fate of Asbestos?

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### Learning Objectives

Upon completion of this section, you will be able to

- Identify where asbestos fibers are most likely to be retained in the body.

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### Introduction

Inhaled asbestos fibers are deposited in the upper and lower respiratory tracts. The durability and retention of the fibers in lung tissue and elsewhere in the body may lead to a risk of disease.

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**Deposition in Lungs**

Asbestos particles occur in many sizes in inhaled air. The largest size asbestos particles tend to deposit on the nasal mucosa or the oropharynx and are sneezed out or swallowed and never reach the lungs [NIOSH 2011a].

Some of the smaller inhaled asbestos fibers are deposited on the surface of the larger airways where some of them are cleared by mucociliary transport and swallowing. Other smaller fibers are deposited further down in the lung, especially in the bifurcations of the tracheobronchial tree, and some are deposited in the alveolar sacs [Broaddus 2001].

There has been much scientific discussion about how fiber size affects the pathogenicity of asbestos. It is believed that the dimensions of the asbestos fiber determines how far into the lungs it is likely to be deposited and how quickly it is cleared. Wide fibers (diameter greater than 2 to 5 microns) tend to be deposited in the upper respiratory tract and cleared. Some recent papers have shown cumulative fiber exposure to be an important risk factor for the development of asbestosis [Larson et al. 2010a].

However, it is important to remember that asbestos fibers of all lengths cannot be excluded as contributors to asbestos-related diseases [Dodson et al. 2003].

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**Fate in Lungs**

Once deposited in the lungs, asbestos fibers are subject to several lung defenses.

- The most important means of removal of insoluble asbestos particles deposited in respiratory tract airways is by mucociliary clearance. This cleared material is usually swallowed and enters the gastrointestinal tract; however, the asbestos coughed out in sputum is eliminated from the body [NIOSH 2011a].
- The most important means of removal of insoluble asbestos particles deposited in the alveoli involves alveolar macrophages. These specialized cells generally function to clear particles depositing in the alveoli by enveloping them in a process called phagocytosis and then moving to the airways, where the particle-containing macrophages are transported out of the lungs via mucociliary clearance.

In some cases, insoluble particles are not easily cleared from the alveoli by alveolar macrophages.

- Some (e.g., crystalline silica) particles are highly reactive and toxic to the macrophage cells, which die before they can clear the engulfed particles.
- Under "overload" conditions so many particles are inhaled that they overwhelm the ability of alveolar macrophages to clear them from the alveoli.
- With increasing particle dimension greater than about 15 microns, phagocytosis by macrophages becomes increasingly ineffective. The inability of macrophages to engulf such particles results in "frustrated phagocytosis" [NIOSH 2011a].

Some asbestos fibers deposited in alveoli make their way to the lymphatic system of the lungs, which helps clear fibers from the lungs [Dodson et al. 2003]. Still, many asbestos fibers are retained in lung tissue for many years. The total burden of residual fibers in the lungs depend not only the size of the fibers but the amount of fibers inhaled from the environment [Dodson et al. 2003].



Figure 4. Asbestos fiber retained in lung tissue

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<b>Movement Out of Lungs</b>	From the lungs, some asbestos fibers (mainly short fibers) can migrate to pleural and peritoneal spaces, especially following patterns of lymphatic drainage [Broaddus 2001]. Their presence in the peritoneum is more likely if there is a high fiber burden in the lungs.
<b>Half-Life in the Lungs</b>	How rapidly the body's defenses can clear asbestos fibers from the lungs depends in part on the type of asbestos. While all types of fibers are retained for many years in the lungs [ATSDR 2001a], amphibole fibers are degraded more slowly than serpentine fibers of the same dimensions [Hillerdal 1999].
<b>Fate of Ingested Asbestos</b>	Most ingested asbestos fibers pass through the gastrointestinal tract unchanged and are cleared in the feces. A few ingested fibers pass through the walls of the gastrointestinal tract. Some of these fibers stay in the peritoneal cavity. Others move into the bloodstream and into the kidneys, where some are eliminated unchanged in the urine.

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**Key Points**

- Some inhaled asbestos fibers reach the lungs, where they become lodged in lung tissue, especially at bifurcations and in the lower lung fields.
- Some fibers move to pleural or peritoneal spaces or the mesothelium.
- The half-lives of asbestos fibers vary, but some are retained in the lungs for many years.
- Ingested asbestos fibers are usually eliminated from the body.

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**Progress Check**

9. Some inhaled asbestos fibers that reach the lungs
- A. Become lodged and are retained in lung tissue.
  - B. Migrate to other spaces.
  - C. Are eliminated via phagocytosis.
  - D. All of the above.

*To review relevant content, see "Fate in Lungs" and "Movement Out of the Lungs" in this section.*

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## How Does Asbestos Induce Pathogenic Changes?

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**Learning Objectives**

Upon completion of this section, you will be able to

- Describe the hypothesis behind the mechanisms scientists currently believe leads asbestos to induce pathogenic changes in the lungs.

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**Introduction**

The main determinants of asbestos toxicity are

- Fiber size,
- Biopersistence,
- Chemical composition, and
- Particle surface characteristics [NIOSH 2011a].

The presence of asbestos fibers in the lungs sets off a variety of responses leading to inflammation, cell, and tissue damage, which can lead to malignant and non-malignant diseases.

The mechanisms by which asbestos causes disease are not fully understood. Currently, there are three hypotheses to account for the pathogenicity of asbestos:

1. Direct interaction with cellular chromosomes,
2. Generation of reactive oxygen species, and
3. Other cell-mediated mechanisms (especially inflammation).

Asbestos is genotoxic and carcinogenic.

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**Interaction with Cellular Macromolecules**

Because of their surface charge, asbestos fibers can adsorb to cellular macromolecules (proteins, DNA, RNA) and cell surface proteins. Binding of asbestos fibers to these cellular components is believed to induce changes in macromolecular conformation, thereby affecting macromolecule function.

Long asbestos fibers have been shown to interfere physically with the mitotic spindle and cause chromosomal damage, especially deletions [Broaddus 2001; ATSDR 2001; National Academy of Sciences 2006].

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<b>Release of Reactive Oxygen Species</b>	<p>Asbestos fibers in lung and other tissue are also believed to cause the formation and release of reactive oxygen species (ROS). That is, when alveolar macrophages attempt to engulf and fail to digest an asbestos fiber, they release lysosomal contents into the alveolar space [NIOSH 2011a]. This “frustrated phagocytosis” can generate reactive oxygen species (ROS): hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), and the super oxide radical anion (O<sup>2-</sup>) [Kamp and Weitzman 1999, 1997]. All these ROS induce tumor necrosis factor-alpha (TNF-α). TNF-α is a potent inflammatory cytokine currently felt to play an important role in pulmonary fibrosis [NIOSH 2011a].</p>
<b>Other Cell-Mediated Mechanisms</b>	<p>The presence of asbestos fibers also causes alveolar macrophages, lung cells, and pleural cells to release cellular factors (such as leukotrienes, prostaglandins ) that lead to multiple cellular processes such as</p> <ul style="list-style-type: none"> <li>• Apoptosis,</li> <li>• Cell and DNA damage,</li> <li>• Cell proliferation,</li> <li>• Inflammation, and</li> <li>• Macrophage recruitment.</li> </ul> <p>The exact role of all these cellular processes in the formation of fibrosis and malignancy is still being defined [Broaddus 2001; Kamp et al. 2002].</p>
<b>Primary Sites Affected</b>	<p>When inhaled, asbestos fibers tend to deposit in the lung at the bronchiolar-alveolar duct bifurcations; some are deposited in the smaller airways and alveolar sacs. From the lung, some fibers can migrate into the pleural space by different mechanisms [National Academy of Sciences, 2006].</p> <p>Biopersistence in the lung and the subsequent tendency to cause inflammatory changes is based on fiber durability. In addition to the low ph (4.8) of phagocytosis, a fiber is exposed to extracellular fluids in the lungs (ph =7) which may gradually dissolve it [NIOSH 2011a].</p>

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**Carcinogenicity** Asbestos has been designated as a known human carcinogen by the agencies shown in the table below. All types of asbestos are carcinogenic, but some scientists believe that the amphibole type is more potent in causing mesotheliomas than the serpentine type (chrysotile) [IARC 2012]. However, both types can cause mesotheliomas and lung cancer [ATSDR 2001].

**Table 4. Carcinogenicity of Asbestos**

<b>Agency</b>	<b>Carcinogenicity</b>	<b>Description</b>
International Agency for Research on Cancer (IARC)	1	Known human carcinogen
U.S. Environmental Protection Agency	Group A	Known human carcinogen

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**Key Points**

- The three processes hypothesized to account for asbestos's pathogenicity are
  1. Direct interaction with chromosomes,
  2. Generation of reactive oxygen species (ROS), and
  3. Other cell-mediated mechanisms (especially inflammation induced by TNF- $\alpha$ ).
- Asbestos induces pathological changes leading to such outcomes as fibrosis and malignancy.
- Asbestos is genotoxic and carcinogenic.

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10. Asbestos induces pathogenic changes in lung tissue via

- A. Direct interaction with chromosomes.
- B. Generation of active oxygen species.
- C. Cell-mediated inflammatory mechanisms.
- D. All of the above.

*To review relevant content, see "Introduction" in this section.*

11. As a result of its pathogenic actions, asbestos

- A. Induces fibrotic changes in lung tissue.
- B. Is genotoxic.
- C. Is carcinogenic.
- D. All of the above.

*To review relevant content, see "Introduction" and "Carcinogenicity" in this section.*

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## **What Respiratory Conditions Are Associated with Asbestos?**

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### **Learning Objectives**

Upon completion of this section, you will be able to

- Describe the most common respiratory conditions associated with asbestos exposure.
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**Introduction**

According to the American Thoracic Society [2004], "asbestos has been the largest cause of occupational cancer in the United States and a significant cause of disease and disability from nonmalignant disease." It has been estimated that the cumulative total number of asbestos-associated deaths in the United States may exceed 200,000 by the year 2030 [Nicholson et al. 1982].

Depending on the level and duration of exposure, inhalation of asbestos fibers can cause different diseases such as

- Asbestosis,
- Asbestos-related pleural abnormalities,
- Lung and laryngeal carcinoma, and/or
- Malignant mesothelioma of the pleura or peritoneum.

Any combination of these diseases can be present in a single patient. Clinically, it is important to distinguish nonmalignant conditions from malignant diseases; differential diagnosis will be discussed further in later sections of this document.

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**Asbestosis**

Asbestosis is a diffuse interstitial fibrosis of lung tissue resulting from inhalation of asbestos fibers. Asbestos fibers inhaled deep into the lung become lodged in the tissue, eventually resulting in diffuse alveolar and interstitial fibrosis. The fibrosis usually first occurs in the respiratory bronchioles, particularly in the subpleural portions of the lower lobes. The fibrosis can progress to include the alveolar walls. Fibrosis tends to progress even after exposure ceases [Khan et al. 2013]. This fibrosis can lead to

- Reduced lung volumes,
- Decreased lung compliance,
- Impaired gas exchange,
- Restrictive pattern of impairment,
- Obstructive features due to small airways disease, and
- Progressive exertional dyspnea with an insidious onset.

Asbestosis is characterized by the following radiographic changes: fine, irregular opacities in both lung fields (especially in the bases) and septal lines that progress to honeycombing and sometimes, in more severe disease, obscuration of the heart border and hemidiaphragm—the so-called shaggy heart sign [Khan et al. 2013]. Radiographic changes depend on the

- Duration,
- Frequency, and
- Intensity of exposure.



Figure 5. Chest radiograph of asbestosis in the lung

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Patients with asbestosis may have elevated levels of antinuclear antibody and rheumatoid factors and a progressive decrease in total lymphocyte count with advancing fibrosis.

Asbestosis has no unique pathognomonic signs or symptoms, but diagnosis is made by the constellation of clinical, functional, and radiographic findings as outlined by the American Thoracic Society [American Thoracic Society 2004]. These criteria include

- Sufficient history of exposure to asbestos,
- Appearance of disease with a consistent time interval from first exposure,
- Clinical picture such as insidious onset of dyspnea on exertion, bibasilar end-inspiratory crackles not cleared by coughing,
- Functional tests showing restrictive (occasionally obstructive) pattern with reduced diffusing capacity (DLco),
- Characteristic radiographic appearance, and
- Exclusion of other causes of interstitial fibrosis or obstructive disease such as usual interstitial pneumonia, connective tissue disease, drug-related fibrosis [American Thoracic Society 2004; Khan et al. 2013].

The table below describes the natural history associated with asbestosis.

<b>Table 5. Natural History of Asbestosis</b>	
<b>Parameter</b>	<b>Typical Findings</b>
Sufficient exposures	Usually associated with high-level occupational exposures [Khan et al. 2013].

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Latency periods	Radiographic changes: commonly <20 years. Clinical manifestations: commonly 20-40 years. Asbestosis appears earliest in those with the highest exposure levels [American Thoracic Society 2004].
Risk of asbestosis	Asbestosis develops in around 50% of adults with occupational asbestos exposure [Khan et al. 2013].
Co-morbid conditions	Increased risk for asbestos-related lung cancer and mesothelioma, though both can occur without asbestosis [Weiss 1999; Hillerdal 1999].
Mortality and Morbidity	Severe asbestosis may lead to respiratory failure over 1-2 decades. Many patients with asbestosis die of other causes such as asbestos-associated lung cancer (38%), mesothelioma (9%), and other causes (32%) [Rosenberg 1997, Kamp and Weitzman 1997].

**Asbestos-Related Pleural Abnormalities**

Asbestos-related pleural abnormalities encompass four types of pleural changes.

1. Pleural plaques.
2. Non-malignant asbestos pleural effusions.
3. Diffuse pleural thickening.
4. Rounded atelectasis (folded lung).

The pleura are more sensitive to asbestos than the lung parenchyma, so the effects of asbestos exposure show

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here first and occur at much lower doses than the fibrotic changes in the lung [Peacock et al. 2000; Khan et al. 2013].



Figure 6. Chest radiograph showing bilateral pleural plaques

*Pleural plaques* are well-circumscribed areas of thickening, usually located bilaterally on the parietal pleura. They are usually asymptomatic, though they can cause small reductions in lung function [American Thoracic Society 2004]. On rare occasions (<1%), pleural plaques can cause pleuritic pain requiring medical pain management [Harbut 2007; Harbut et al. 2009]. Pleural plaques are the most common manifestations of asbestos exposure; by occupation, the highest rate (58%) has been reported in insulation workers [American Thoracic Society 2004; Peacock et al. 2000]. The presence of pleural plaques in the general environmentally exposed population in developed societies is in the range of 0.5%-8% [Khan et al. 2013]. Indeed, they are considered a biomarker of asbestos exposure, depending more on length from first exposure, than on cumulative exposure [Peacock et al. 2000]. Pleural plaques can also form following exposure to

- Ceramic fibers,
- Talc,
- Silicates,

- 
- Erionite, a rare zeolite [Finkelstein 2013; Clark et al. 2006; Zenden et al. 1997].

*Non-malignant asbestos pleural effusions* are small and often bloody unilateral effusions [Khan et al. 2013]. These effusions are among the earliest manifestations of asbestos exposure; they can occur within 10 years of exposure [Chapman et al. 2003]. They are usually asymptomatic. Rarely, they can cause pain, fever, and dyspnea. These effusions typically last for months, and may occasionally recur. Their presence can precede the occurrence of diffuse pleural thickening [Chapman et al. 2003].

*Diffuse pleural thickening* is a non-circumscribed fibrous thickening of the visceral pleura with areas of adherence to the parietal pleura and obliteration of the pleural space. It can be associated with more extensive asbestos exposure than pleural plaques [Chapman et al. 2003]. And, diffuse pleural thickening, in fact, has been reported to occur in 10% of patients with asbestosis [Khan et al. 2013]. Diffuse pleural thickening can occur after non-malignant pleural effusions. The fibrotic areas are ill-defined, involving costophrenic angles, apices, lung bases, and interlobar fissures. Diffuse pleural thickening can be associated with mild (or, rarely, moderate to severe) restrictive pulmonary function deficits such as decreased ventilatory capacity. When this occurs, the patient may experience progressive dyspnea and chest pain [Chapman et al. 2003].

*Rounded atelectasis (or folded lung)* occurs when portions of lung tissue are caught in bands of fibrous pleural tissue with in-drawing of the bronchi and vessels [Khan et al. 2013]. This produces a distinctive radiographic appearance: a rounded pleural mass with bands of lung tissue radiating outwards. This condition is usually asymptomatic, though some patients develop dyspnea or dry cough. The course is usually stable or slowly progressive. Folded lung is the least common asbestos-related non-malignant pleural disease; it is not only associated with asbestosis exposure but can occur following other exposures and medical conditions. However, asbestos exposure is the leading cause of

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rounded atelectasis, accounting for 29%-86% of cases. It can rarely also co-occur with lung cancer [Stathopoulos et al. 2005].

The differential causes of rounded atelectasis includes

- Exposure to mineral dusts such as asbestos, and occupational exposures to silica and mixed mineral dusts;
- Exudative pleural effusions such as
  - Empyema,
  - Tuberculous effusions,
  - Hemothorax,
  - Post-cardiac surgery,
  - Chronic hemodialysis; and
- Other medical conditions such as
  - *Legionella* pneumonia,
  - Histoplasmosis,
  - End-stage renal disease,
  - Pneumothorax, and
  - Childhood cancer [Stathopoulos et al. 2005].

The table below shows typical findings and natural history associated with asbestos-related non-malignant pleural abnormalities.

**Table 6. Natural History and Findings of Asbestos-related Pleural Abnormalities**

Parameter	Pleural Plaques	Pleural Effusions	Diffuse Pleural Thickening	Rounded Atelectasis

<b>Typical Exposures</b>	Can occur with short low-level exposures or high-level occupational exposures.		Usually associated with moderate-to high-level exposures. Less specific for asbestos exposure than pleural plaques	May occur with occupational and environmental exposures. Has other causes besides asbestos exposure.
<b>Average Latency Periods</b>	20–30 years	10 years	15 years	N/A
<b>Co-morbid Conditions</b>	Since the presence of these plaques is an indicator of asbestos exposure, there is an increased incidence of asbestos-related diseases associated with them.	Other asbestos-related diseases.	Other asbestos-related diseases. Can follow non-malignant pleural effusions.	Follows non-malignant pleural effusions; can co-exist with other asbestos-related diseases or its other causes.

<b>Mortality and Morbidity</b>	Not fatal/usually asymptomatic; incidental finding.	Not fatal. Clinical presentation ranges from asymptomatic to pleuritic chest pain and fever.	Not fatal. If severe, can cause dyspnea.  Usually no significant functional impairment unless very extensive.	Not fatal. Usually asymptomatic; if severe, chest pain, dyspnea, and cough. Usually no functional impairment unless accompanied by other asbestos-related disease.
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Source: American Thoracic Society 2004; Chapman et al. 2003; Khan et al. 2013; Stathopoulos et al. 2005

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**Lung Carcinoma** Most lung cancers are associated with exposure to tobacco smoke. According to the 2004 Surgeon General Report on smoking, men with a lifetime of smoking have a 16 percent higher risk of dying from lung cancer over their lifetimes than those who do not smoke [Surgeon General 2004] Lung cancer currently accounts for 28% of all cancer deaths in the United States [Minna 2005].

Exposure to asbestos is associated with all major histological types of lung carcinoma (adenocarcinoma, squamous cell carcinoma, and small-cell carcinoma). It is estimated that 4%-12% of lung cancers are related to occupational levels of exposure to asbestos [Henderson et al. 2004]. It is estimated that 20%-25% of heavily exposed asbestos workers will develop bronchogenic carcinomas [Khan et al. 2013]. Whether asbestos exposure will lead to lung cancer depends on several factors:

- Level, duration, and frequency of asbestos exposure (cumulative exposure) [Henderson et al. 2004],
- Time elapsed since exposure occurred,
- Age when exposure occurred,
- History of tobacco use, and
- Individual susceptibility factors not yet determined.

Most asbestos-related lung cancers reflect the dual influence of asbestos exposure and smoking [Henderson et al. 2004]. It has been known for over 25 years, that smoking and asbestos exposure have a multiplicative effect on the risk of lung cancer [Lee 2001; Henderson et al. 2004; ATSDR 2001]. The presence of asbestosis is an indicator of high-level asbestos exposure, but lung cancer can occur without asbestosis.

One of the best known sets of criteria to guide the clinician regarding whether asbestos contributed to lung cancer in an asbestos-exposed individual is the Helsinki criteria. For these criteria, some of the markers for attributing asbestos exposure as a contributing factor to lung cancer are

- The presence of asbestosis – serves as marker for significant exposures to asbestos,
- Estimated cumulative exposure to asbestos of at least 25 fiber-years (if known),
- By history, at least 1 year of heavy occupational exposure or 5-10 years of moderate exposure, and
- Lag time of at least 10 years since first exposure [Henderson et al. 1997].

The table below shows typical findings associated with lung carcinoma.

<b>Table 7. Findings Associated with Lung Carcinoma</b>	
<b>Parameter</b>	<b>Typical Findings</b>
Typical exposures	Large cumulative exposure (short-term, high-level exposures or long-term, moderate-level exposures).
Latency periods	20–30 years.
Clinical presentation	Only 5%-15% of patients are asymptomatic when diagnosed. Most present with cough, hemoptysis, wheeze, dyspnea [Minna 2005].
Co-morbid conditions	Asbestosis, other asbestos-related diseases. Paraneoplastic syndromes associated with lung cancer.
Mortality	Same as lung carcinoma with other causes - 14% five-year survival rate [British Thoracic Society 2001].

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**Pleural Mesothelioma**

Diffuse malignant mesothelioma is a tumor arising from the thin serosal membrane of the body cavities:

- Pleura,
- Peritoneum,
- Pericardium,
- Tunica vaginalis testis, and
- Outer surface of ovaries.

It is a rare neoplasm, accounting for less than 5% of pleural malignancies. There are three histological types of malignant mesothelioma:

1. Epithelial,
2. Mixed, and
3. Sarcomatous.

Of malignant mesotheliomas, 80% affect the pleura, and 20% of all malignant mesotheliomas affect the peritoneum [Khan et al. 2013]. A 2003 report of mesothelioma incidence in Australia reported pleural mesotheliomas at 93.2%, peritoneal mesotheliomas at 6.5% and mesotheliomas of other rare sites at 0.3% [Leigh and Driscoll 2003]. Peritoneal mesothelioma is discussed in the next section.

In most cases of pleural mesothelioma, the tumor is rapidly invasive locally [Lee et al. 2000]. Patients with malignant pleural mesothelioma can have sudden onset of pleural effusion and/or pleural thickening, dyspnea, and chest pain. By the time symptoms appear, the disease is most often rapidly fatal [British Thoracic Society 2001].

Pleural mesothelioma is a signal tumor for asbestos exposure; other causes are uncommon. The risk of mesothelioma depends on the amount of asbestos exposure [Weill et al. 2004]. All types of asbestos can cause mesothelioma, but some researchers believe that the amphibole form is more likely to induce mesothelioma than the serpentine form [ATSDR 2001a].

In 2007, about 2,700 people in the United States died of mesothelioma [NIOSH 2012a]. According to the National

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Cancer Institute's Surveillance Epidemiology and End Results [SEER] data, there was an increase in the incidence of mesothelioma in the United States from the early 1970s to the mid-1990s, as disease developed in people exposed during peak asbestos exposure years (1940–1970). Mesothelioma incidence has probably started to decline in the United States, although it may still be increasing in Europe and Australia because of more abundant and prolonged use of asbestos in these countries than in the United States [Weill et al. 2004].

The table below shows typical findings associated with pleural mesothelioma.

<b>Table 8. Findings Associated with Pleural Mesothelioma</b>	
<b>Parameter</b>	<b>Typical Findings</b>
Typical exposures	Short-term, high-level exposures or chronic low-level exposures, especially to amphibole asbestos; incidence increases in dose-related manner [Hillerdal 1999].
Latency periods	10–57 years (30–40 years typical).
Clinical presentation	Frequently presents with chest pain accompanied by pleural mass or pleural effusion on chest radiograph [Thoracic Society 2001].
Mortality	High. The typical 1-year survival rate is <30%. Median survival time is 8–14 months after diagnosis [British Thoracic Society 2001].

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**Key Points**

- Asbestosis is an interstitial pulmonary fibrosis resulting from inhalation of asbestos fibers. It produces a restrictive pattern of disease and progressive exertional dyspnea.
- Asbestos-related pleural abnormalities include
  - Pleural plaques,
  - Non-malignant pleural effusions,
  - Diffuse pleural thickening, and
  - Rounded atelectasis.

They are relatively benign conditions, though diffuse pleural thickening can cause restrictive deficits.

- Lung carcinoma caused by asbestos exposure is histologically similar to lung cancer from other causes.
- Malignant pleural mesothelioma is a rare tumor arising from the pleural mesothelium. It is a signal tumor for asbestos exposure.
- Asbestos-associated respiratory diseases have long latency periods: 10 to 40 years or more, depending on the disease and exposure factors.

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**Progress Check**

12. Diffuse interstitial fibrosis resulting from inhalation of asbestos and producing restrictive lung disease and progressive exertional dyspnea is termed
- A. Lung carcinoma.
  - B. Pleural mesothelioma.
  - C. Asbestosis.
  - D. Asbestos-related pleural abnormalities.

*To review relevant content, see "Asbestosis" in this section.*

13. Asbestos-related non-malignant pleural abnormalities include which of the following
- A. Pleural plaques.
  - B. Pleural effusions and diffuse pleural thickening.
  - C. Rounded atelectasis.
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D. All of the above.

*To review relevant content, see "Asbestos-Related Pleural Abnormalities" in this section.*

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## **What Other Health Conditions Are Associated with Asbestos?**

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### **Learning Objectives**

Upon completion of this section, you will be able to

- Identify non-respiratory conditions that might be associated with exposure to asbestos.

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### **Introduction**

Evidence indicates that exposure to asbestos leads to conditions outside the respiratory system, including

- Peritoneal mesothelioma,
  - Other extra-thoracic cancers, and
  - Cardiovascular conditions secondary to pulmonary fibrosis.
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**Peritoneal Mesothelioma**

Peritoneal mesothelioma is similar to pleural mesothelioma except that it arises in peritoneal membranes. Like pleural mesothelioma, this tumor is rapidly locally invasive and often rapidly fatal after it is diagnosed.

Peritoneal mesothelioma is rare. In men, 90% of all mesotheliomas are pleural [Weill et al. 2004]. In addition, the sex difference in incidence is smaller with peritoneal mesothelioma than for pleural mesothelioma [Hillerdal 1999].

The table below shows male to female incidence ratios for the two different types of mesothelioma.

<b>Table 9. Sex Ratios for Different Types of Mesothelioma</b>	
<b>Type of Mesothelioma</b>	<b>Male:Female Incidence Ratio</b>
Pleural	5:1
Peritoneal	1.5:1
Source: Hillerdal 1999	

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**Other Extra-thoracic Cancers**

Researchers and regulators have not been able to reach a consensus on the effects of asbestos on extra-thoracic cancers. Both the Institute of Medicine (IOM) and the International Agency for Research on Cancer (IARC) have reviewed the state of the evidence regarding the role of asbestos in causing selected extra-thoracic cancers. The recent IARC panel determinations are presented below.

<b>Table 10. Other Extra-thoracic Cancers</b>	
<b>Type of Cancer</b>	<b>Evidence for Causality by Asbestos</b>
Laryngeal	Sufficient evidence for increased risk in asbestos-exposed workers

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Ovary	Sufficient evidence for increased risk in asbestos-exposed women
Pharyngeal	Evidence for associated risk from asbestos exposure is suggestive but not sufficient. More research is needed.
Stomach	Evidence for associated risk from asbestos exposure is suggestive but not sufficient.
Colorectal	Evidence for risk from asbestos exposure is suggestive but not sufficient. More research is needed. The IARC working group was evenly divided on whether the evidence was sufficient to designate causality.
Esophageal	Inadequate evidence exists to determine the risk from asbestos exposure.
Source: IARC 2012	

Despite the lack of scientific consensus on the role of asbestos in gastrointestinal cancers, ATSDR and the National Toxicology Program (NTP) concur that it is prudent to consider increased risk of gastrointestinal cancer a possible effect of asbestos exposure [ATSDR 2001a; American Thoracic Society 2004; National Toxicology Program 2011]. Colon cancer screening starting at age 50 is recommended using accepted guidelines [Agency for Healthcare Research and Quality, 2008] but on the basis of current evidence, screening for other extrathoracic cancers in people exposed to asbestos is not currently recommended [American Thoracic Society 2004; Griffith and Maloney 2003].

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**Cardiovascular Conditions**

Cor pulmonale occurs in many forms of far advanced lung disease when fibrosis of the lungs leads to increased resistance to blood flow through the capillary bed. This condition is most commonly seen in patients with severe asbestosis, though it can also occur with less severe fibrotic disease, especially if chronic obstructive pulmonary disease is simultaneously present, as is often the case with asbestos workers who have been smokers.

Constrictive pericarditis rarely occurs secondary to severe asbestos-induced fibrosis or calcification of the pericardium.

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**Key Points**

- Pleural and peritoneal mesothelioma is a rare, rapidly invasive tumor caused by asbestos exposure.
  - Asbestos exposure is a known risk factor for laryngeal cancer and ovarian cancer.
  - Asbestos exposure might be associated with some other extrathoracic cancers, especially colon cancer.
  - Cor pulmonale can occur secondary to pulmonary fibrosis, mainly in patients with severe asbestosis.
  - Rarely, constrictive pericarditis can occur secondary to asbestos-associated disease.
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**Progress  
Checks**

14. Exposure to asbestos is indicated by
- A. Malignant mesothelioma of the pleura or peritoneum.
  - B. Gastrointestinal cancer.
  - C. Other extra-thoracic cancers.
  - D. All of the above.

*To review relevant content, see "Peritoneal Mesothelioma" in this section.*

15. The cardiovascular condition most likely to occur secondary to pulmonary fibrosis is
- A. Endocarditis.
  - B. Constrictive pericarditis.
  - C. Cor pulmonale.
  - D. All of the above.

*To review relevant content, see "Cardiovascular Conditions" in this section.*

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## **Clinical Assessment**

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**Learning  
Objectives**

Upon completion of this section, you will be able to

- Identify the primary focuses of the patient exposure history (exposure and medical) and
  - Describe the most typical finding on examination of asbestosis patients.
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**Introduction**

Patients who have been significantly exposed to asbestos should undergo a thorough medical evaluation. Early and accurate diagnosis is important to your choosing the most appropriate care strategies, even if the patient is not exhibiting symptoms. In cases of asbestos exposure, medical evaluation should include

- An assessment of clinical presentation,
- An exposure history (See ATSDR Case Study in Environmental Medicine: Taking an Exposure History),
- A medical history,
- A physical examination, and
- A chest radiograph or other imaging and pulmonary function tests [American Thoracic Society 2004].

This section focuses on the first four items, which are typically conducted during the patient's visit to your office. Recommended tests are discussed in the next section.

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**Clinical Presentation**

Many people with occupational exposure to asbestos never have serious asbestos-related diseases. However, asbestos-associated diseases typically have long latency periods so many patients exposed to asbestos are asymptomatic for years before any clinically apparent asbestos-related disease develops. If and when asbestos-associated disease does manifest clinically, the patient's symptoms depend on the type and stage of disease(s) involved (see table). A single patient can have any combination of asbestos-associated diseases.

**Table 11. Clinical Presentation of Asbestos Associated Diseases**

<b>Asbestos-Associated Disease</b>	<b>Clinical Presentation</b>
Asbestosis	<p>Presenting Symptoms</p> <ul style="list-style-type: none"><li>• Dyspnea on exertion</li><li>• Nonproductive cough</li><li>• Fatigue</li><li>• Signs</li><li>• Wheezing</li><li>• Bibasilar end-inspiratory rales (i.e., crackles) on auscultation of the chest</li></ul> <p>Advanced Stages.</p> <ul style="list-style-type: none"><li>• Clubbing of the fingers</li><li>• Dyspnea at rest</li><li>• Cyanosis</li><li>• Cor pulmonale (rare)</li></ul>
Asbestos-related non-malignant pleural abnormalities	<p>Presenting Symptoms</p> <ul style="list-style-type: none"><li>• Usually none</li><li>• In some cases, intermittent chest pain, rarely can be severe.</li></ul>

Lung cancer	<p>Presenting Symptoms</p> <ul style="list-style-type: none"> <li>• Early in the course, usually none. Sometimes none, if cancer is found incidentally (e.g., on a chest radiograph done for another reason).</li> <li>• Occasionally, dry cough</li> <li>• Advanced Stages</li> <li>• Hemoptysis</li> <li>• Chest pain, usually severe</li> <li>• Weight loss</li> <li>• Fatigue</li> <li>• Dyspnea (due to pleural effusion or obstructive pneumonia)</li> </ul>
Mesothelioma	<p>Presenting Symptoms</p> <ul style="list-style-type: none"> <li>• Frequently presents with chest pain and dyspnea</li> </ul> <p>Advanced Stages</p> <ul style="list-style-type: none"> <li>• Dyspnea (due to space-occupying mass and/or pleural effusion)</li> <li>• Severe and progressive chest pain, sometimes pleuritic in nature</li> <li>• Systemic signs of cancer such as weight loss and fatigue</li> </ul>
<p>Source: British Thoracic Society 2001; American Thoracic Society 2004</p>	

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**Exposure History**

Taking a detailed exposure history is an important step in evaluating a patient who may be at risk for developing asbestos-associated diseases. In general, risk of asbestos-related disease increases with total dose [Khan et al. 2013]. However, since asbestos accumulates in the body, even relatively minor exposures many years in the past could be important in diseases like mesothelioma. The exposure history should include

- Work history, including occupations in which the patient may have been exposed directly or indirectly.
- Source, intensity, frequency and duration of exposure.
- Time elapsed since first exposure.
- If extant, workplace dust measurements or cumulative fiber dose (or exposure scenario, if levels cannot be determined).
- Use of personal protective equipment.
- Other sources of exposure, including paraoccupational exposures from family members and other household contacts.
- Sources of environmental exposure, including residence near an area with naturally occurring asbestos deposits or hobbies or recreational activities that involve materials that contain asbestos).
- Smoking history and sources of other environmental contaminants such as environmental tobacco smoke [American Thoracic Society 2004].

For more information on the exposure history, see the Taking an Exposure History CSEM at <https://www.atsdr.cdc.gov/csem/csem.asp?csem=33&po=0>

See the table below for typical exposures for each of the asbestos-associated diseases.

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**Table 12. Estimated Exposures and Disease Risk for Asbestos**

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Asbestos-Related Disease	Typical Exposure History
Asbestosis	Usually associated with high-level occupational exposures, not with paraoccupational or environmental exposures [Khan et al. 2013].
Asbestos-related non-malignant pleural abnormalities	<p>Presence of <i>pleural plaques</i> depends more on time from first exposure rather than on a threshold dose [Larson et al. 2010b], but the incidence of this disorder in a population does increase with exposure. Occurs in 0.5% to 8% of environmentally exposed individuals and up to 58% of insulation workers [Peacock et al. 2000].</p> <p><i>Non-malignant pleural effusion</i> earliest manifestation of asbestos exposure. They can occur within ten years of asbestos exposure.</p> <p><i>Diffuse pleural thickening</i> is associated with more extensive asbestos exposure than pleural plaques.</p> <p><i>Folded atelectasis</i> not only occurs after asbestos exposure but is associated with other exposures and medical conditions.</p>

Lung cancer	Dose-related. Synergistic relationship with smoking [Jaklitsch et al. 2012].
Mesothelioma	Not as clearly dose-related as other asbestos-related diseases, but the risk does appear to increase with dose. Can be found in residents near asbestos mines and with paraoccupational exposure. [British Thoracic Society 2001].

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**Medical History** Knowing the complete medical history of a patient who has been exposed to asbestos is important to making an accurate diagnosis. It is especially important to ask about a history of smoking and exposure to environmental tobacco smoke, because exposure to tobacco smoke, especially active smoking, can greatly increase risk of lung cancer and can worsen the effects of asbestosis in asbestos-exposed patients.

Particularly for asbestos-related non-malignant diseases, it is important to be aware of other respiratory and non-respiratory conditions that may have similar clinical presentations in order to rule them out.

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**Physical Examination** Patients with a history of asbestos exposure should receive a full physical examination with special attention to the respiratory system. In the case of early or mild disease, there will probably be no abnormal physical findings. The most common abnormal finding with significant asbestosis is bibasilar end-inspiratory rales (i.e., crackles) on auscultation. These are described as sounding like Velcro [Ross 2003].

Physical examination should also include

- Examination for clubbing of the fingers and cyanosis [American Thoracic Society 2004],

- Examination of the extremities for symmetrical dependent edema, one of the physical findings of cor pulmonale,
- Abdominal palpitation for abnormal masses or signs of peritoneal effusion that can accompany peritoneal mesothelioma, and
- Fecal occult blood testing to screen for colorectal cancer screening [CDC 2013].

**Differential Diagnosis**

Several other non-asbestos related respiratory and non-respiratory conditions have symptoms similar to those of asbestos-associated diseases. It is important to distinguish these conditions, for some of which have specific treatments different from asbestos-related non-malignant diseases, for which medical treatment is entirely symptomatic (see table).

It is also important to distinguish non-malignant asbestos-associated conditions from malignant conditions such as lung cancer and mesothelioma. In cases that are not clear cut, a referral to a pulmonary specialist for further workup is indicated.

**Table 13. Differential Diagnosis of Respiratory Conditions that Can Be Confused with Asbestos-related Conditions**

<b>Asbestos-Related Condition</b>	<b>Differential Diagnosis: Respiratory Condition</b>	<b>Differential Diagnosis: Non-Respiratory Condition</b>
Asbestosis	<ul style="list-style-type: none"> <li>• Rheumatoid arthritis and other connective tissue diseases (with pleural or pulmonary involvement)</li> <li>• Other pneumoconiosis:               <ul style="list-style-type: none"> <li>○ Talc</li> <li>○ Titanium</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Left ventricular failure (presents with dyspnea, rales, edema, restriction, and basilar markings on chest film)</li> </ul>

		<ul style="list-style-type: none"> <li>○ Zeolite</li> <li>• Interstitial pulmonary fibrosis (IPF), including idiopathic pulmonary fibrosis</li> <li>• Hypersensitivity pneumonitis</li> <li>• Sarcoidosis</li> <li>• Drug-related fibrosis</li> <li>• Other pulmonary fibrosis</li> </ul>	
Asbestos-related non-malignant pleural disease	<p>Single pleural plaques</p> <ul style="list-style-type: none"> <li>• Malignant mesotheliomas and metastatic adenocarcinomas [Khan et al. 2013]</li> </ul> <p>Single calcified pleural plaques</p> <ul style="list-style-type: none"> <li>• Empyema</li> <li>• Hemothorax</li> <li>• Tuberculosis [Khan et al. 2013]</li> </ul> <p>Bilateral calcified pleural plaques</p> <ul style="list-style-type: none"> <li>• Most commonly asbestos-related but in rare cases <ul style="list-style-type: none"> <li>○ Radiation exposure</li> <li>○ Hyperparathyroidism</li> </ul> </li> </ul>	Prior thoracic surgery/chest wall configuration	

		<ul style="list-style-type: none"> <li>○ Pancreatitis [Khan et al. 2013]</li> </ul> <p>Diffuse pleural thickening</p> <ul style="list-style-type: none"> <li>• Post-exudative effusions such as parapneumonic effusions and those secondary to connective tissue disease</li> <li>• Hemothorax</li> <li>• Mesothelioma [Khan et al. 2013]</li> </ul> <p>Rounded atelectasis (folded lung)</p> <ul style="list-style-type: none"> <li>• Lesions that are similar in appearance to rounded atelectasis (i.e., solitary pulmonary mass) are <ul style="list-style-type: none"> <li>○ Malignancies such as bronchogenic carcinoma, metastasis, lymphoma</li> <li>○ Benign neoplasms such as hamartoma and adenoma</li> <li>○ Vascular causes such as arteriovenous</li> </ul> </li> </ul>	
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		<p>malformation, pulmonary infarct, hematoma</p> <ul style="list-style-type: none"> <li>○ Infections such as tuberculosis, round pneumonia, fungal infections [Khan et al. 2013]</li> </ul>	
Lung carcinoma	<p>Other causes of a solitary pulmonary nodule</p> <ul style="list-style-type: none"> <li>• Folded lung</li> <li>• Metastatic lesion</li> <li>• Lymphoma</li> <li>• Benign neoplasms such as hamartoma or adenoma</li> <li>• Vascular lesion such as a arteriovenous malformation, pulmonary infarction or hematoma</li> <li>• Infectious lesions from tuberculosis, fungal infections [Khan et al. 2013]</li> </ul>		
Malignant mesothelioma	<ul style="list-style-type: none"> <li>• Diffuse pleural thickening</li> <li>• Metastatic adenocarcinoma [Khan et al. 2012; British Thoracic Society 2001]</li> </ul>		

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**Key Points**

- The exposure history focuses on finding information on exposures to asbestos.
- The medical history focuses on smoking history and other respiratory conditions.
- The most typical abnormal finding on examination of patients with a history of asbestos exposure is bibasilar end-inspiratory rales on auscultation.
- Patients with asbestosis present to the clinician with the chief complaint of insidious onset of dyspnea on exertion.
- Asbestos-related non-malignant pleural abnormalities typically do not cause symptoms, although some patients experience progressive dyspnea and chest pain.
- Lung cancer can be asymptomatic, but in the later stages patients experience fatigue, weight loss, chest pain, dyspnea, or hemoptysis.
- Mesothelioma can be asymptomatic, but patients usually present in later stages of the disease, at which point dyspnea and chest pain are common.

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**Progress Checks**

16. The most typical abnormal finding on physical examination of a patient with significant asbestosis is
- A. Cyanosis.
  - B. Bibasilar inspiratory rales on auscultation.
  - C. Clubbing of the fingers.
  - D. All of the above.

*To review relevant content, see "Physical Examination" in this section.*

17. Why is it important to know a patient's exposure history?
- A. Asbestos-associated diseases have symptoms similar to those of treatable diseases, and the exposure history assists a differential diagnosis.
  - B. Activities such as smoking can increase a patient's risk of asbestos-related diseases.
  - C. Asbestos accumulates in the body and, for certain disorders, even minor exposures can be important.
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D. All of the above.

*To review relevant content, see “Exposure History” in this section.*

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## Clinical Assessment – Tests

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### Learning Objectives

Upon completion of this section, you will be able to

- Describe chest radiograph findings associated with other asbestos-associated diseases and
- Describe pulmonary function test findings associated with asbestosis.

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### Introduction

The most important tests in diagnosing asbestos-associated disease are

- Chest radiographs and
- Pulmonary function tests.

Other tests and procedures that are sometimes used to diagnose asbestos-associated diseases by specialists in cases that require further work-up include

- Blood studies,
  - Bronchoalveolar lavage (BAL),
  - Colon cancer screening.
  - Computed tomography (CT) or high-resolution, computerized (axial) tomography (HRCT), and
  - Lung biopsy.
-

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**Screening  
Pulmonary  
Function Tests**

Screening pulmonary function tests are useful for finding restrictive deficits most commonly associated with asbestosis (see table). Findings may include a reduction in forced vital capacity (FVC) with a normal forced expiratory volume (FEV) in one second FEV1/FVC ratio. Some sources report abnormal pulmonary function tests in 50% to 60% of patients with asbestosis [Ross 2003].

In some cases, combined patterns of restrictive and obstructive disease may be seen. For further assessment of whether a patient has a restrictive abnormality and asbestosis, additional, more specialized tests may be required.

- Carbon monoxide diffusion capacity (DLco), which is very sensitive to ventilation-perfusion mismatch and gas exchange abnormalities characteristic of all types of diffuse interstitial pulmonary fibrosis, is reduced in 70% to 90% of asbestosis cases [Ross 2003]. Be aware however that low DLco is a non-specific finding and it can be present in far advanced stages of chronic obstructive pulmonary disease (COPD) as well as in other types of restrictive interstitial diseases.
- Static lung volumes measured by plethysmographic or helium dilution methods.

Consider consulting a pulmonologist if the diagnosis is unclear, if there is a rapid decline in pulmonary function, or if there is a potential need for a tissue biopsy or BAL, such as in cases where lung cancer, mesothelioma, or an infection is suspected. The pulmonologist may recommend more extensive pulmonary function tests.

<b>Table 14. Pulmonary Function Test Results Associated with Asbestos-related Diseases</b>	
<b>Asbestos-Associated Disease</b>	<b>Findings</b>

Asbestosis	<p>Restrictive spirometry pattern (i.e., low FVC with normal FEV1/FVC ratio.</p> <p>Mixed obstructive/restrictive spirometry pattern (i.e., reduced FEV1/FVC ratio with reduced FEV1) [American Thoracic Society 2004].</p> <p>Decreased DLco [American Thoracic Society 2004].</p>
Asbestos-related pleural abnormalities	Normal pattern or if extensive pleural involvement, restrictive spirometry pattern [Larson et al. 2012].

**Chest Radiograph**

The chest radiograph is used primarily to find, localize, and assess the extent of structural changes associated with asbestos-caused chest diseases (asbestosis, non-malignant pleural disease, mesothelioma, and lung cancer).

Diagnosis of asbestosis should mostly but not totally be based on radiographic findings, per the diagnostic criterion of the American Thoracic Society. In 10% to 15% of cases, an asbestos-associated pulmonary function abnormality can occur without definite radiologic change [Ross 2003]. The association of pleural thickening and calcification with interstitial changes enhances diagnostic accuracy of asbestosis.

During the latter half of the past century, the International Labour Office (ILO) developed a system for radiographic classification of the pneumoconiosis. It now includes a set of standard digital radiographic images or a set of standard plain film images. [ILO 2011, NIOSH 2011b] Persons certified by the National Institute of Occupational Safety and Health (NIOSH) as proficient in the use of this rating system are called "B Readers." Most epidemiological studies of pneumoconiosis use B

Readers to classify radiographs according to the ILO system.

A current list of B Readers can be found at <http://www.cdc.gov/niosh/topics/chestradiography/breader-list.html>. Classification of asbestosis by chest radiography should be guided by the ILO system.

A list of typical chest radiograph findings for each of the asbestos-associated diseases is in the table below.

Figure 7. Radiographic images associated with asbestos-related diseases		
		
Pleural Plaques	Pleural Mesothelioma	Asbestosis

Table 15. Typical Radiographic Findings for Asbestos-related Diseases	
Asbestos-Associated Disease	Typical Chest Radiograph Findings
Asbestosis	<p>Small, irregular opacities in both lung fields, predominating at the lung bases.</p> <p>Diffuse, bilateral interstitial fibrosis.</p> <p>With advanced disease, combined interstitial and pleural involvement can blur</p>

	<p>the heart border (also known as the “shaggy heart sign”).</p> <p>Honeycombing and upper lobe involvement in near end-stage disease.</p>
Asbestos-related Non-malignant Pleural Abnormalities	<p><b>Pleural Plaques</b></p> <p>Often multiple bilateral well-circumscribed areas of thickening found on the pleura, sometimes with calcification (10%-15%) [Khan et al. 2013].</p> <p><b>Non-malignant Pleural Effusions</b></p> <p>Indistinguishable from other pleural effusions, but usually small and can be either unilateral or bilateral.</p> <p><b>Diffuse Pleural Thickening</b></p> <p>Smoothly thickened parietal pleura often associated with obscuration of the costophrenic angle [Khan et al. 2013].</p> <p>Sometimes, prominent interlobar fissures).</p> <p><b>Rounded Atelectasis</b></p> <p>Appears as a rounded intrapulmonary mass abutting on thickened pleura, with bands of lung tissue radiating outwards.</p>
Lung cancer	<p>Radiological appearance same as that of lung cancers with other causes (<i>e.g.</i>, solitary pulmonary mass with or without mediastinal lymphadenopathy).</p>

Mesothelioma	May present as a <ul style="list-style-type: none"> <li>• Pleural effusion,</li> <li>• Pleural mass, or</li> <li>• A diffuse pleural thickening.</li> </ul>
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### CT and HRCT

In some cases, computed tomography (CT) scans, including high-resolution computed tomography (HRCT) scans, due to their greater sensitivity and specificity than conventional chest radiographs [Paris et al. 2009] can facilitate diagnosis of asbestos-associated diseases such as lung fibrosis [Vierikko et al. 2010]. Because they are associated with higher doses of radiation than conventional chest radiographs and their cost-effectiveness and efficiency as screening tools have not been established, CT scans are not currently recommended in the United States for routine screening of asbestosis of the general population.

They can be useful in further investigating abnormalities found on chest radiographs and in detecting abnormalities not seen on chest films of patients with dyspnea or pulmonary function abnormalities such as decreased DLco [Vierikko et al. 2010].

CT and HRCT scans are more sensitive and specific than chest radiographs. HRCT scans can be used particularly when abnormalities on a conventional chest radiograph are equivocal or when a conventional chest radiograph is normal in the face of unexplained lung function abnormalities in a patient with significant asbestos exposure [American Thoracic Society 2004]. They are especially useful in detecting

- Early parenchymal abnormalities of asbestosis,
- Early pleural disease, such as plaques and rounded atelectasis,
- The difference between asbestos-associated pleural plaques and extra-pleural fat, and
- Mesothelioma [British Thoracic Society 2001].

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However, HRCTs are recommended for use in screening special populations at high risk of lung cancer such as people with smoking histories of 15 to 30 pack years and those with some occupational exposures such as asbestos, arsenic, chromium, silica, nickel, cadmium, beryllium and diesel fumes [Bach et al. 2012; NIOSH 2012b].

The utility of other imaging techniques such as ultrasound, gallium scanning, magnetic imaging, ventilation-perfusion studies, and positron emission tomography has not been established in asbestos-related disease.

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**BAL and Lung Biopsy**

Bronchoalveolar lavage (BAL) is sometimes used by specialists to identify other possible causes for lung pathology. It can be used to assess exposure to asbestos by measuring the amount and type of asbestos bodies and asbestos fibers in the lavage fluid [American Thoracic Society 2004]. Not only is this a somewhat invasive procedure requiring fiberoptic bronchoscopy, but the laboratory procedures are not routinely available; special laboratory facilities and expertise are required.

Lung biopsy is a definitive test used in the histopathological confirmation of asbestos-associated diseases. Lung biopsies are rarely used to diagnose asbestosis or pleural plaques, because diagnosis of these conditions is usually based on medical and exposure histories, findings from the physical examination, and other tests. Appropriate referral to a specialist is indicated if lung cancer or mesothelioma is suspected, since a lung biopsy will be indicated under these conditions.

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**Blood Studies**

Blood studies may occasionally be useful for ruling out other causes of restrictive lung disease.

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**Colon Cancer Screening**

Evidence increasingly shows that asbestos exposure increases an exposed patient's risk for colon cancer [IARC 2012]. Therefore, it is important to perform colon cancer screening on asbestos exposed patients starting at age 50 according to current guidelines [Agency for Health Care Research and Quality 2008].

The joint guidelines from the American Cancer Society, the U.S. multi-society task force for colorectal cancer, and the American College of Radiology can be found at: <http://www.ncbi.nlm.nih.gov/pubmed/18322143> [Levin et al. 2008].

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**False Positives and False Negatives**

It is important to know what other conditions bear radiographic similarities to changes associated with asbestos-related disease (see table).

<b>Asbestos-Associated Disease</b>	<b>Similar Radiographic Appearance</b>
Asbestosis	<ul style="list-style-type: none"><li>• Left ventricular failure.</li><li>• Other forms of pulmonary fibrosis, including other forms of pneumoconiosis.</li></ul>
Asbestos-related non-malignant pleural abnormalities	<p>General differential diagnoses</p> <ul style="list-style-type: none"><li>• Acute infectious pleuritis (including empyema and pleural tuberculosis).</li><li>• Previous surgery or chest wall trauma.</li><li>• Past empyema or infected pleural effusion.</li></ul>

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	<p>Pleural plaques may be confused with</p> <ul style="list-style-type: none"> <li>• Extra-pleural fat,</li> <li>• Muscle shadows,</li> <li>• Pleural thickening from old rib fractures</li> </ul> <p>Non-malignant asbestos-related pleural effusions may be confused with</p> <ul style="list-style-type: none"> <li>• Malignant pleural effusion and</li> <li>• Multiple other causes of pleural effusion, including tuberculosis, congestive heart failure, etc.</li> </ul> <p>Diffuse pleural thickening may be confused with</p> <ul style="list-style-type: none"> <li>• Mesothelioma,</li> <li>• Healed empyema,</li> <li>• Old chest trauma, and/or</li> <li>• Old chest surgery.</li> </ul> <p>Rounded atelectasis</p> <ul style="list-style-type: none"> <li>• Bronchogenic carcinoma.</li> <li>• Mesothelioma.</li> <li>• Pleural-based lung cancer or metastasis to the pleura.</li> </ul>
Lung cancer	Lung cancer not related to asbestos.
Mesothelioma	All other causes of unilateral pleural masses.

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**Attribution of Asbestos-Related Cause** To help attribute pulmonary fibrosis to asbestos exposure, check for the diagnostic guidelines suggested by the American Thoracic Society:

- Characteristic appearance on radiographic chest imaging or, when lung tissue is available, tissue histopathology.
- Exposure history (with appropriate latency period); and/or asbestos bodies or uncoated fibers found in sputum, BAL, or lung tissue; and/or pleural plaques (as a marker of exposure) and
- Other causes unlikely.
- Other findings that aid in documenting disease attributable to asbestos exposure include
  - Abnormal spirometry test results (restrictive and/or obstructive pattern),
  - Low DLco, and
  - Auscultatory signs such as characteristic rales [Holland and Smith 2003; American Thoracic Society 2004].

Bilateral calcified pleural plaques are usually attributable to asbestos exposure, but unilateral pleural plaques should motivate a search for other causes such as old tuberculosis, empyema, or hemothorax. CT scanning is useful to make a definite diagnosis of rounded atelectasis [Khan et al. 2013].

As stated previously, sets of diagnostic criteria like the Helsinki criteria can help in attributing an individual patient's lung cancer to asbestos exposure.

Malignant mesotheliomas are, for all practical purposes, readily attributable to past asbestos exposure.

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**Key Points**

- Asbestosis is commonly associated with restrictive patterns on spirometry.
  - Signs of asbestosis on chest radiograph include interstitial fibrosis and the “shaggy heart sign.”
  - On chest radiograph, pleural plaques appear as well-circumscribed areas of pleural thickening, sometimes with calcification.
  - On chest radiograph, pleural effusions caused by asbestos have the same appearance as effusions from other causes, though they are typically small.
  - On chest radiograph, diffuse pleural thickening appears as a smooth prominence along the chest wall and interlobar fissure thickening, often with obscuration of the costophrenic angle.
  - On chest radiograph, findings associated with rounded atelectasis appear as a rounded intrapulmonary mass that abuts on thickened pleura and has radiating bands of lung tissue.
  - Asbestos-associated lung cancer has the same appearance as lung cancer from other causes.
  - Chest radiograph findings associated with mesothelioma include pleural effusions or a pleural mass.
  - CT and HRCT scans can be useful to clarify questionable pleural or parenchymal findings, and in diagnosing mesothelioma.
  - Other tests that can be useful include BAL, lung biopsy, and colon cancer screening.
-

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**Progress  
Check  
Questions**

18. The two most important tests for diagnosing asbestos-associated diseases are
- A. BAL and lung biopsy.
  - B. CT and HRCT scans.
  - C. Chest radiograph and pulmonary function tests.
  - D. Blood studies and colon cancer screening.

*To review relevant content, see "Introduction" in this section.*

19. Diffuse, small, irregular opacities are characteristic radiographic findings with
- A. Asbestosis.
  - B. Lung cancer.
  - C. Mesothelioma.
  - D. All of the above.

*To review relevant content, see "Chest Radiograph" in this section.*

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## **How Should Patients Exposed to Asbestos Be Treated and Managed?**

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**Learning  
Objectives**

Upon completion of this section, you will be able to

- Identify two primary strategies for managing asbestos-associated diseases and
  - Describe specific strategies for managing asbestosis.
-

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**Introduction**

Asbestos-associated diseases such as asbestosis and pleural plaques are not curable. Some complications of asbestos-related disease like acute pleuritis are self-limited. Management focuses on prevention and amelioration of symptoms in the patient with asbestos-related disease. Therefore, the primary actions are to

- Avoiding further exposure to asbestos if that is currently occurring,
- If currently employed in a job that entails asbestos exposure, the patient should be referred to an occupational specialist who can advise the patient on avoiding further exposures through the use of personal protective equipment (PPE) and well ventilated work spaces, and can provide important advice regarding the legal and occupational issues that work with asbestos entails, and
- Monitor the patient to facilitate early diagnosis and treatment of any treatable respiratory conditions associated with asbestos.

Patients who are symptomatic may need documentation of impairments caused by asbestos-associated disease for the purpose of filing for workers compensation, social security disability, or other claims. Explanation of the specific statute of limitations for filing of workers compensations should be explained; the different states will have differing laws regarding workers compensation claims. Degree of disability should be stated in the terms required by the program to which the patient is applying. Recording these impairments and advising on legal issues associated with occupational asbestos-related disease is an important task and may require the assistance of a specialist such as an occupational physician. To locate such a specialist, please refer to the Web resources listed under "Sources of Additional Information" at the end of this CSEM.

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The remainder of this section focuses on patient care.

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**All Exposed Patients**

Care of patients who have been exposed to asbestos, whether or not they are symptomatic, involves routine follow up to facilitate early diagnosis and intervention. This includes

- Exposure and medical histories and regular physical examinations,
- Periodic chest radiographs and pulmonary function tests to look for early signs of asbestos-associated disease,
- Encouraging smoking cessation for patients who smoke, and
- Educating patients regarding the possible consequences of asbestos exposure.

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**Asbestosis**

Asbestosis is irreversible, and the rate of disease progression varies [American Thoracic Society 2004]. Currently, there is no specific effective treatment.

Patients with advanced disease and hypoxemia at rest, during exercise, or during sleep may benefit from continuous home oxygen therapy, which can prevent or attenuate cor pulmonale. However, primary management strategies for asbestosis are listed below.

- Remove the patient from the source of exposure if there is any ongoing exposure. If occupational exposure is currently ongoing, refer the patient to an occupational physician for advice on achieving cessation or amelioration of this occupation related issue.
  - Assess the patient's level of disability.
  - Treat chest infections aggressively.
  - Provide pneumococcal vaccine and annual influenza vaccines as recommended by Centers for Disease Control and Prevention.
  - Provide respiratory therapies and pulmonary rehabilitation as needed.
  - Counsel patients who smoke to quit.
  - Counsel patients to call you if they notice any changes in their health such as weight loss, change in cough, coughing up blood.
  - Notify the appropriate health authorities in states where asbestosis is reportable.
-

- 
- Follow the general strategies listed for all patients.

Patients should be monitored periodically (per doctor-patient consultation) for disease progression and closely observed for asbestos-associated malignancies such as lung cancer, mesothelioma, and other cancers [American Thoracic Society 2004; IARC 2012]. Colon cancer screening should begin at age 50 and follow standard guidelines [Levin et al. 2008]

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**Pleural Abnormalities**

Pleural plaques are generally benign, but can occasionally result in pulmonary impairment. As mentioned previously, when severe pleuritic pain accompanies asbestos-related pleural disease, it requires appropriate management [Harbut et al. 2009]. In addition, patients with asbestos-related pleural abnormalities may have or eventually get asbestosis or asbestos-related cancers. Therefore, management of asbestos-related pleural abnormalities involves monitoring for asbestosis and all known related malignancies and the general strategies listed for all patients.

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**Mesothelioma**

Diffuse malignant mesothelioma is almost always fatal. Median life expectancy following diagnosis ranges from 8 to 14 months in various studies [British Thoracic Society 2001].

For more information about the diagnosis and treatment of mesothelioma, see

- British Thoracic Society Standards of Care Committee, Statement on malignant mesothelioma in the United Kingdom [British Thoracic Society 2001].

The National Cancer Institute's latest news on the treatment of mesothelioma at <http://www.cancer.gov/cancertopics/types/malignantmesothelioma/>.

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**Lung Cancer**

The treatment and management of asbestos-associated lung cancer is the same as that of lung cancer from other causes.

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**Key Points**

- The two primary strategies for managing non-malignant asbestos-associated diseases.
    - For all patients, occupational and nonoccupational who have current asbestos exposure, remove the patient from further exposure to asbestos.
    - If a worker with exposure to asbestos, consult with or refer patient to an occupational specialist for advice regarding personal protective equipment, work situation and medico-legal issues such as worker's compensation and notifications.
    - Monitor the patient carefully to facilitate early diagnosis of treatable complications.
  - The primary strategies for managing asbestosis are to stop or limit exposure, stop smoking, prevent or aggressively treat chest infection, and assess the level of impairment.
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**Progress Checks**

20. Primary strategies for managing asbestos-associated diseases include

- A. Smoking cessation.
- B. Periodic pulmonary function tests.
- C. Patient education.
- D. All of the above.

*To review relevant content, see "Introduction" in this section.*

21. Managing asbestosis involves

- A. Smoking cessation.
- B. Providing pneumococcal and annual influenza vaccines as recommended by Centers for Disease Control and Prevention.
- C. Respiratory therapies and pulmonary rehabilitation.
- D. All of the above.

*To review relevant content, see "Asbestosis" in this section.*

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## What Instructions Should Be Given to Patients Exposed to Asbestos?

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**Learning Objectives**

Upon completion of this section, you will be able to

- List four instructions for patient self-care and
- Describe two instructions for clinical follow-up.

**Introduction**

Patients with a history of asbestos exposure will vary widely in their clinical status. Some will be asymptomatic and will continue to be so for life. Some will be beginning to show signs of asbestos-associated disease, and others will have more established disease. The care you provide will depend on the clinical status of the patient. All patients exposed to asbestos, however, need some basic guidance on

- Self-care, so they can minimize further risks and avoid complications to the extent possible and
-

- Clinical follow-up, so they understand when and why to return for further medical attention.

ATSDR has developed a Patient Care and Education Instruction sheet on asbestos toxicity. It is designed to provide patients with useful information and advice for caring for themselves. It can be found at the end of this case study.

---

**Self Care**

Patients should be advised to avoid exposures and conditions that might further increase their risk of disease or worsen their existing condition.

<b>Table 17. Self-care Advice to Asbestos-exposed Patients</b>	
<b>Advice</b>	<b>Rationale</b>
If the patient smokes, advise them to stop smoking and provide advice on smoking cessation. All patients should avoid exposure to environmental tobacco smoke.	Smoking decreases lung defenses, dramatically increases risk of lung cancer in case of asbestos exposure, and worsens effects of asbestosis.
Avoid further exposure to asbestos.	Further exposure to asbestos can worsen asbestos related disease.
Avoid exposure to respiratory infections especially influenza and pneumonia.	Chest infections can be very serious in people with asbestos-associated respiratory conditions.

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<b>Clinical Follow-up</b>	<p>Patients should be advised to consult their physicians if they develop</p> <ul style="list-style-type: none"> <li>• Any sign or symptom of chest infection and/or</li> <li>• Signs or symptoms of other health changes such as weight loss, change in cough, coughing up blood (these especially since they could possibly be related to an asbestos-associated disease).</li> </ul> <p>ATSDR's Patient Care Instruction and Education sheet has a more detailed checklist that you can use to determine which types of follow-up are relevant for a given patient.</p>
<b>Key Points</b>	<ul style="list-style-type: none"> <li>• Counsel patients as follows: <ul style="list-style-type: none"> <li>○ If a current smoker, stop smoking,</li> <li>○ Avoid environmental tobacco smoke and further exposure to asbestos,</li> <li>○ Avoid exposure to respiratory infections, and</li> <li>○ Contact their physician if you have a chest infection or other health changes.</li> </ul> </li> <li>• Use the Patient Education and Care Instruction sheet and prescribed follow up check list on asbestos toxicity at <a href="http://www.atsdr.cdc.gov/csem/asbestos_2014/docs/asbestos_patient_education.pdf">http://www.atsdr.cdc.gov/csem/asbestos_2014/docs/asbestos_patient_education.pdf</a> .</li> </ul>
<b>Progress Check</b>	<p>22. Patients with significant past exposure to asbestos should</p> <ol style="list-style-type: none"> <li>A. Stop smoking.</li> <li>B. Avoid further exposure to asbestos.</li> <li>C. Avoid exposure to respiratory infections and contact their doctor if they develop signs of chest infection or other health changes.</li> <li>D. All of the above.</li> </ol> <p><i>To review relevant content see "Introduction" in this section.</i></p>

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## Sources of Additional Information

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**Asbestos  
Specific  
Information**

Please refer to the following Web resources for more information on the adverse effects of asbestos, the treatment of asbestos-associated diseases, and management of persons exposed to asbestos.

- Agency for Toxic Substances and Disease Registry (ATSDR) <http://www.atsdr.cdc.gov>

- For chemical, emergency situations

- CDC Emergency Response: 770-488-7100 and request the ATSDR Duty Officer

**PLEASE NOTE**

ATSDR cannot respond to questions about **individual medical cases**, provide second opinions, or make specific recommendations regarding therapy. Those issues should be addressed directly with your health care provider.

- For chemical, non-emergency situations

- CDC-INFO <http://www.cdc.gov/cdc-info/>
- 800-CDC-INFO (800-232-4636) TTY 888-232-6348 - 24 Hours/Day
- E-mail: [cdcinfo@cdc.gov](mailto:cdcinfo@cdc.gov)

- Toxic Substances Portal – Asbestos

- <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=4>

- Toxicological Profile for Asbestos

- <http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=30&tid=4>

- TOXFAQs for Asbestos

- <http://www.atsdr.cdc.gov/toxfaqs/TF.asp?id=29&tid=4>

- TOXFAQs for Asbestos (Spanish)

- [http://www.atsdr.cdc.gov/es/toxfaqs/es\\_tfacts61.html](http://www.atsdr.cdc.gov/es/toxfaqs/es_tfacts61.html)

- Centers for Disease Control and Prevention (CDC) <http://www.cdc.gov/>
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- National Institute of Safety and Health (NIOSH) Safety and Health Topic - Chest Radiography: <http://www.cdc.gov/niosh/topics/chestradiography/>
  - ILO Classification System - [http://www.ilo.org/safework/info/publications/WCMS\\_168260/lang--en/index.htm](http://www.ilo.org/safework/info/publications/WCMS_168260/lang--en/index.htm)
  - U.S. Environmental Protection Agency <http://www.epa.gov>
  - Occupational Safety and Health Administration <http://www.osha.gov>

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**General Environmental Health Information**

Please refer to the following Web resources for general information on environmental health.

- Agency for Toxic Substances and Disease Registry <http://www.atsdr.cdc.gov>
  - Taking an Exposure History CSEM <https://www.atsdr.cdc.gov/csem/csem.asp?csem=33&po=0>
  - To view the complete library of CSEMs <http://www.atsdr.cdc.gov/csem/csem.html>
  - Exposure History Worksheet <http://www.atsdr.cdc.gov/csem/exphistory/docs/CSEMExposHist-26-29.pdf>
  - ATSDR Division of Regional Operations.
    - Through the working relationships they have established with EPA, other federal and state agencies, individual citizens, and community groups, regional representatives are able to maintain current and historic knowledge of the sites and issues in their regions.
    - ATSDR's Regional Offices, along with the states and territories that they cover as well as contact information, can be found at [http://www.atsdr.cdc.gov/DRO/dro\\_contact.html](http://www.atsdr.cdc.gov/DRO/dro_contact.html)
  - ATSDR State Cooperative Agreement Program <http://www.atsdr.cdc.gov/states/index.html>

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- The Cooperative Agreement Program provides essential support in communities nationwide to fulfill the mission of the Agency for Toxic Substances and Disease Registry (ATSDR).
  - The program funds 30 states and one tribal government to develop and strengthen their abilities to evaluate and respond to environmental public health issues.
- Centers for Disease Control and Prevention (CDC)  
<http://www.cdc.gov>
    - CDC works to protect public health and the safety of people, by providing information to enhance health decisions, and promotes health through partnerships with state health departments and other organizations.
    - The CDC focuses national attention on developing and applying disease prevention and control (especially infectious diseases), environmental health, occupational safety and health, health promotion, prevention and education activities designed to improve the health of the people of the United States.
  - National Center for Environmental Health (NCEH)  
<http://www.cdc.gov/nceh>
    - NCEH works to prevent illness, disability, and death from interactions between people and the environment. It is especially committed to safeguarding the health of populations that are particularly vulnerable to certain environmental hazards - children, the elderly, and people with disabilities.
    - NCEH seeks to achieve its mission through science, service, and leadership.
  - National Institute of Health (NIH)  
<http://www.nih.gov>
    - A part of the U.S. Department of Health and Human Services, NIH is the primary Federal
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agency for conducting and supporting medical research.

- National Institute of Occupational Safety and Health (NIOSH) <http://www.cdc.gov/niosh/>
    - NIOSH is in the U.S. Department of Health and Human Services and is an agency established to help assure safe and healthful working conditions for working men and women by providing research, information, education, and training in the field of occupational safety and health.
  
  - American College of Occupational and Environmental Medicine (ACOEM) <http://www.acoem.org/>
    - ACOEM is the nation's largest medical society dedicated to promoting the health of workers through preventive medicine, clinical care, research, and education.
    - Its members are a dynamic group of physicians encompassing specialists in a variety of medical practices united via the College to develop positions and policies on vital issues relevant to the practice of preventive medicine both within and outside of the workplace.
  
  - American College of Medical Toxicologists (ACMT) <http://www.acmt.net>
    - ACMT is a professional, nonprofit association of physicians with recognized expertise in medical toxicology.
    - The College is dedicated to advancing the science and practice of medical toxicology through a variety of activities.
  
  - American College of Preventive Medicine (ACPM) <http://www.acpm.org>
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- ACPM is the national professional society for physicians committed to disease prevention and health promotion.
  - ACPM's 2,000 members are engaged in preventive medicine practice, teaching and research.
  - Association of Occupational and Environmental Clinics (AOEC) <http://aoec.org>
    - AOEC is a network of more than 60 clinics and more than 250 individuals committed to improving the practice of occupational and environmental medicine through information sharing and collaborative research.
  - Pediatric Environmental Health Specialty Units (PEHSUs) <http://www.pehsu.net>
    - PEHSU form a respected network of experts in children's environmental health.
    - The PEHSU were created to ensure that children and communities have access to, usually at no cost, special medical knowledge and resources for children faced with a health risk due to a natural or human-made environmental hazard.
    - Located throughout the United States, Canada, and Mexico, PEHSU professionals provide quality medical consultation for health professionals, parents, caregivers, and patients. The PEHSUs are also dedicated to increasing environmental medicine knowledge among healthcare professionals around children's environmental health by providing consultation and training.
  - American Association of Poison Control Center (AAPC) <http://www.aapcc.org>
    - The American Association of Poison Control Centers can be contacted for questions about poisons and poisonings. The web site provides information about poison centers and poison
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prevention. AAPC does not provide information about treatment or diagnosis of poisoning or research information for student papers.

- American Association of Poison Control Centers may be contacted at 1-800-222-1222.
- The U.S. National Library of Medicine's Toxicology and Environmental Health Information Program (TEHIP) <http://sis.nlm.nih.gov/enviro.html>
  - TEHIP maintains a comprehensive toxicology and environmental health web site that includes access to resources produced by TEHIP and by other government agencies and organizations.
  - This web site includes links to databases, bibliographies, tutorials, and other scientific and consumer-oriented resources.
  - TEHIP also is responsible for the Toxicology Data Network (TOXNET®), an integrated system of toxicology and environmental health databases that are available free of charge on the web <http://toxnet.nlm.nih.gov>

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**Suggested Reading**

For further information on asbestos-associated diseases, please refer to

American Thoracic Society. 2004. Diagnosis and initial management of nonmalignant diseases related to asbestos. *American Journal of Respiratory and Critical Care Medicine* 170:691-715.

British Thoracic Society Standards of Care Committee. 2001. Statement on malignant mesothelioma in the United Kingdom. *Thorax* 56:250-265.

Peipins L, Lewin M, Campolucci S, Lybarger JA, Miller A, Middleton D, et al. 2003. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana. *Environmental Health Perspectives* 111(14):1733-1739.

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**Posttest**

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**Posttest**

1. What is asbestos?
    - A. A group of naturally occurring fibrous silicate minerals.
    - B. A fibrous substance used widely throughout the United States in the construction, shipbuilding, and automotive industries until the 1970s.
    - C. A heat-stable substance commonly used in insulation, pipe coverings, boilers, brake pads, and many other products.
    - D. All of the above.
  
  2. Which asbestos exposure pathway most commonly leads to illness?
    - A. Ingestion.
    - B. Inhalation.
    - C. Dermal contact.
    - D. All are equally important.
  
  3. Of the following, in the United States, the people in the general population most at risk of exposure to asbestos today are
    - A. People who work in asbestos mining and milling.
    - B. Household contacts of workers engaged in the manufacture of asbestos-containing products.
    - C. People working or living in homes and buildings with loose, crumbling, or disturbed asbestos materials.
    - D. People who garden with vermiculite potting soil.
  
  4. OSHA requires workers who are exposed to asbestos at levels higher than the PEL of 0.1 fibers/cc of air (8-hour TWA) to
    - A. Receive medical surveillance.
    - B. Be hospitalized immediately.
    - C. File claims for work-related injuries.
    - D. All of the above.
  
  5. After inhalation, asbestos fibers
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- A. Are retained in the lungs, especially the lower lung fields.
  - B. Initiate responses that can lead to fibrosis of lung tissue.
  - C. Initiate responses that can lead to carcinogenesis.
  - D. All of the above.
6. Of the respiratory conditions associated with asbestos exposure, the condition that is not malignant but is associated with significant restrictive deficits is
- A. Asbestosis.
  - B. Asbestos-related pleural abnormalities.
  - C. Lung carcinoma.
  - D. Pleural mesothelioma.
7. Which condition is most likely to occur secondary to asbestos-associated pulmonary fibrosis?
- A. Peritoneal mesothelioma.
  - B. Colon cancer.
  - C. Cor pulmonale.
  - D. Constrictive pericarditis.
8. The most important risk factor for asbestos-associated diseases are
- A. Genetic polymorphisms and exposure to air pollution.
  - B. Total exposure to asbestos and smoking.
  - C. Frequency of respiratory infections and coexistence of other fibrotic respiratory conditions.
  - D. All are equally important.
9. A 64-year-old male who worked in shipyards in the United States in the 1960s and 1970s presents to his physician complaining of breathlessness, especially when he works or exercises. He says this symptom began several years ago but was so minor that he was not concerned. He also complains of a
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- slight, nagging dry cough. Of the asbestos-associated diseases, the most likely culprit is
- A. Asbestosis.
  - B. Asbestos-related pleural abnormalities.
  - C. Lung carcinoma.
  - D. Pleural mesothelioma.
10. On auscultation of a patient with asbestosis, you are most likely to hear
- A. Normal breath sounds.
  - B. Absent breath sounds.
  - C. Bibasilar end inspiratory rales.
  - D. Rhonchi.
11. As part of taking the exposure history, you should explore
- A. Possible occupational exposures to asbestos.
  - B. Possible paraoccupational and secondary exposures to asbestos.
  - C. Use of personal protective equipment.
  - D. All of the above.
12. Pulmonary function tests of a patient with asbestosis are most likely to show
- A. Normal results.
  - B. Low FVC.
  - C. Low FEV1.
  - D. Low FEV1/FVC.
13. On chest radiograph, small, irregular opacities in the bases of both lung fields is suggestive of
- A. Asbestosis.
  - B. Pleural plaques.
  - C. Benign asbestos pleural effusion.
  - D. Diffuse pleural thickening.
14. In caring for a patient who was exposed to asbestos, it is important to
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- A. Take steps to avoid further exposure to asbestos.
- B. Counsel the patient to stop smoking.
- C. Monitor the patient to facilitate early treatment of chest infections.
- D. All of the above.
15. Patients diagnosed with an asbestos-associated disease should be instructed to
- A. Continue working with asbestos as long as they use PPE.
- B. Contact their doctor if they develop any sign of respiratory infection or other health change.
- C. Receive influenza and pneumococcal vaccines only if they meet other criteria for being high risk.
- D. All of the above.
16. Asbestos fibers are released into the air mainly when
- A. Asbestos-containing materials are loose, crumbling, or disturbed.
- B. Asbestos is fixed in solid materials such as wallboard.
- C. Asbestos-bearing rock lays unexposed deep underground.
- D. All of the above.
17. Which of the following is EPA's MCL for asbestos in drinking water?
- A. 0.07 fibers per liter of drinking water.
- B. 7 million fibers per liter of drinking water.
- C. 700 fibers per liter of drinking water.
- D. 70,000 fibers per liter of drinking water.
18. Diffuse interstitial fibrosis resulting from inhalation of asbestos fibers and producing restrictive lung disease and progressive exertional dyspnea is termed
- A. Lung carcinoma.
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- B. Pleural mesothelioma.
  - C. Asbestosis.
  - D. Asbestos-related pleural abnormalities.
19. Asbestos-related pleural abnormalities include which of the following?
- A. Pleural plaques.
  - B. Benign pleural effusions and diffuse pleural thickening.
  - C. Rounded atelectasis.
  - D. All of the above.
20. The most typical abnormal finding on physical examination of a patient with significant asbestosis is
- A. A “doughy” feeling in the abdomen.
  - B. Bibasilar inspiratory rales on pulmonary auscultation.
  - C. Clubbing of the fingers.
  - D. All of the above.
21. The two most important tests for diagnosing asbestos-associated diseases are
- A. BAL and lung biopsy.
  - B. CT and HRCT scans.
  - C. Chest radiograph and pulmonary function tests.
  - D. Blood studies and colon cancer screening.
22. Managing asbestosis involves
- A. Smoking cessation.
  - B. Annual influenza and pneumococcal vaccines as recommended by the Centers for Disease Control.
  - C. Respiratory therapies and pulmonary rehabilitation.
  - D. All of the above.
23. Patients who were exposed to asbestos should
- A. Stop smoking.
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- B. Avoid further exposure to asbestos.
- C. Avoid exposure to respiratory infections and contact their doctor if they get signs of infection or other health changes.
- D. All of the above.

**Relevant Content**

To review content relevant to the posttest questions, see:

Question	Location of Relevant Content
1	What Is Asbestos? <ul style="list-style-type: none"> <li>• Explain what asbestos is</li> </ul>
2	How Are People Exposed to Asbestos <ul style="list-style-type: none"> <li>• Identify the most important route of exposure to asbestos which leads to health effects.</li> </ul>
3	Who Is at Risk of Exposure to Asbestos <ul style="list-style-type: none"> <li>• Name the populations most heavily exposed to asbestos</li> <li>• Describe who is at risk of domestic exposure to asbestos</li> </ul>
4	What Are U.S. Standards for Asbestos Levels <ul style="list-style-type: none"> <li>• Explain the OSHA PEL for asbestos</li> </ul>
5	What Is the Biological Fate of Asbestos <ul style="list-style-type: none"> <li>• Identify where asbestos fibers are most likely to be found in the body</li> </ul> How Does Asbestos Induce Pathogenic Change <ul style="list-style-type: none"> <li>• Describe the mechanisms by which scientists hypothesize asbestos</li> </ul>

		induces pathogenic changes in the lungs
6	What Respiratory Diseases Are Associated with Asbestos	<ul style="list-style-type: none"> <li>Describe the four respiratory conditions associated with asbestos exposure</li> </ul>
7	What Other Diseases Are Associated with Asbestos	<ul style="list-style-type: none"> <li>Identify non-respiratory conditions that might be associated with exposure to asbestos</li> </ul>
8	How Should Patients Exposed to Asbestos Be Evaluated	<ul style="list-style-type: none"> <li>Identify the primary focuses of the patient exposure history</li> </ul>
9	How Should Patients Exposed to Asbestos Be Evaluated	<ul style="list-style-type: none"> <li>Identify the primary focuses of the patient exposure history</li> </ul>
10	How Should Patients Exposed to Asbestos Be Evaluated	<ul style="list-style-type: none"> <li>Describe the most typical finding on the patient evaluation</li> </ul>
11	How Should Patients Exposed to Asbestos Be Evaluated	

	<ul style="list-style-type: none"> <li>Identify the primary focuses of the patient exposure history (exposure and medical) history and</li> </ul>
12	<p>What Tests Can Assist with Diagnosis of Asbestos-related Disease?</p> <ul style="list-style-type: none"> <li>Describe pulmonary function tests associated with asbestosis</li> </ul>
13	<p>What Tests Can Assist with Diagnosis of Asbestos-related Disease?</p> <ul style="list-style-type: none"> <li>Describe chest radiograph findings associated with other asbestos-associated diseases</li> </ul>
14	<p>How Should Patients Exposed to Asbestos Be Treated and Managed</p> <ul style="list-style-type: none"> <li>Identify two primary strategies for managing asbestos associated diseases</li> </ul>
15	<p>What Instructions Should Be Given to Patients</p> <ul style="list-style-type: none"> <li>List two instructions for clinical follow-up</li> </ul>
16	<p>Where is asbestos found</p> <ul style="list-style-type: none"> <li>Describe how asbestos is released into the air</li> </ul>
17	<p>What Are U.S. Standards for Asbestos Levels</p> <ul style="list-style-type: none"> <li>Explain the EPA maximum contaminant level for asbestos in drinking water</li> </ul>

18	<p>What Respiratory Diseases Are Associated with Asbestos</p> <ul style="list-style-type: none"> <li>Describe the four respiratory conditions associated with asbestos exposure</li> </ul>
19	<p>What Respiratory Diseases Are Associated with Asbestos</p> <ul style="list-style-type: none"> <li>Describe the four respiratory conditions associated with asbestos exposure</li> </ul>
20	<p>How Should Patients Exposed to Asbestos Be Evaluated</p> <ul style="list-style-type: none"> <li>Describe the four respiratory conditions associated with asbestos exposure</li> </ul>
21	<p>What Tests Can Assist with Diagnosis of Asbestos-related Disease?</p> <ul style="list-style-type: none"> <li>Describe chest radiograph findings associated with other asbestos-associated diseases</li> </ul>
22	<p>How Should Patients Exposed to Asbestos Be Treated and Managed</p> <ul style="list-style-type: none"> <li>Describe specific strategies for managing asbestosis.</li> </ul>
23	<p>What Instructions Should Be Given to Patients</p> <ul style="list-style-type: none"> <li>List four instructions for patient self-care</li> </ul>

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17. Self-care advice to asbestos-exposed patients

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<b>Figure</b>	<b>Title</b>
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1.	Photo of serpentine asbestos
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2.	Photo of amphibole asbestos
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3.	Map of 28 ATSDR priority sites out of 245 Libby vermiculite mining and processing sites
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4.	Asbestos fiber retained in lung tissue
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5.	Chest radiograph of asbestosis in the lung
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6.	Chest radiograph showing bilateral pleural plaques
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7.	Radiographic images associated with asbestos-related diseases
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