***Chapter 3***

***Health Effects***

***Introduction***

A linkage between asbestos and human health has been recognized for many centuries. During the first century AD, both Romans and Greeks wrote of a disorder of the lungs in slaves who were responsible for weaving asbestos into cloth. The association of asbestos with chronic respiratory disease had to be rediscovered, however, in the modern era.

A number of nonmalignant and malignant conditions are now known to be related to asbestos exposure. These include asbestosis, lung cancer, mesothelioma and other cancers and conditions.

In 1899, a London physician, Dr. Montague Murray, was conducting an autopsy on the body of a textile weaver when he discovered that the worker’s lungs contained dense, fibrous growths. During the 1920s, physicians’ reports regarding unusual lung disease among their patients who worked with asbestos prompted the British government to sponsor a two-year study of asbestos workers. In their 1930 report, the researchers stated that 26.2% of the workers examined showed fibrosis due to asbestos and that this condition could lead to complete disability and death. The fibrotic condition caused by asbestos ultimately became known as “asbestosis.”

In 1935 the American Journal of Cancer reported that the lungs of a dead asbestos weaver contained, in addition to extensive fibrosis, a large carcinoma. This public report helped to establish the link between asbestos exposure and lung cancer.

During the 1960s, numerous South African crocidolite miners were reportedly dying of a form of tuberculosis that was unresponsive to traditional antibiotic therapy. Dr. Chris Wagner discovered that many of these cases of "TB" were actually mesothelioma, a rare and fatal cancer of the tissue (mesothelium) that covers the internal organs and lines the chest and abdominal cavities.

The evidence today describes a range of health risks associated with asbestos exposure. Depending on a number of exposure factors, risks may include asbestosis and lung cancer as well as pleural (chest) and peritoneal (abdominal) mesothelioma, malignancies seldom found in the general population. Moreover, asbestos exposure has been linked to gastrointestinal and other cancers and disorders.

***Diseases Associated with Asbestos Exposure***

Several diseases and conditions have been linked to asbestos fiber inhalation. These include asbestosis, lung cancer, mesothelioma, gastrointestinal cancers and other disorders.

An informative source of information on the health effects of airborne asbestos is a publication from The Health Effects Institute (HEI) entitled "*Asbestos in Public and Commercial Buildings: A Literature Review and Synthesis of Current Knowledge*" (1991). HEI’s Asbestos Literature Review Panel was charged with determining what was known, not known, and uncertain about the risks of exposure to asbestos in public buildings. The main research goals were: (1) to determine the actual airborne asbestos fiber levels prevalent in buildings, (2) to characterize peak exposure levels and their significance, and (3) to evaluate the effectiveness of asbestos management and abatement strategies in a scientifically meaningful manner. This document is a useful reference for regulatory agency personnel.

Other sources of asbestos information include the World Health Organization as well as two federal agencies within the U. S. Department of Health and Human Services – the Agency for Toxic Substances and Disease Registry (ATSDR) and the Centers for Disease Control and Prevention (CDC).

***Asbestosis***

Asbestosis is a progressive, disabling and potentially fatal disease caused by inhalation of asbestos fibers. Inhaled asbestos fibers cause inflammation (alveolitis) to occur, which may result in the development of scarring and fibrosis and subsequent impairment of gas exchange. The extent of damage to the lungs is dependent upon the amount of asbestos in the lungs and individual susceptibility.

Common symptoms of asbestosis include fatigue, shortness of breath, chest pain, a dry or productive cough and rales (a crackling sound heard posteriorly in the bases of the lungs). Asbestosis appears radiologically, e.g., in x-rays, as irregular linear opacities predominantly in the lower lobes.

There is a linear relationship between asbestos exposure and the development of asbestosis – the greater the exposure, the greater the likelihood of developing the disease. Asbestosis is prevalent among workers who have been exposed to large doses of asbestos fibers over a long period of time. These include miners, millers, manufacturers of asbestos products, insulators, shipyard workers, physical plant maintenance workers and veteran custodians. Like all asbestos-related diseases, asbestosis has a long latency period, typically 15-30 years.

Many individuals with asbestosis may suffer from asbestos-related lung cancer as well, although the relationship between lung fibrosis and cancer is unclear.

Individuals who use appropriate safety precautions as described in this course are projected to have little risk of developing asbestosis as a result of their work.

***Lung Cancer***

Asbestos exposure may cause lung cancer, a malignant tumor that invades and obstructs the lung's air passages. The most common symptoms of lung cancer are coughing (including coughing up blood), wheezing, unexplained weight loss and labored breathing. Other symptoms include shortness of breath, persistent chest pain, hoarseness and anemia. People who develop any of these symptoms do not necessarily have lung cancer, but should consult a physician.

The risk of lung cancer, like asbestosis and other asbestos diseases, is higher with greater exposure and exhibits a long latency period, typically 20-30 years.

Studies have shown that asbestos workers who did not smoke cigarettes but experienced heavy asbestos exposure in industrial and construction settings, e.g., cigarette filter and pipe insulation manufacturing, insulating/fireproofing work and work in ship building and repair had a five-fold greater risk of developing lung cancer than that of unexposed non-smokers. Smokers, on the other hand, with no known asbestos exposure, have a 13- to 23-fold increased risk of developing lung cancer compared to non-smokers. Individuals who smoke cigarettes AND were exposed to asbestos under the industrial situations of the past have a 50- to 84-fold increased risk of developing lung cancer. This greatly increased risk resulted from the synergistic effect of the unhealthy components of tobacco smoke and asbestos and the magnitude of the asbestos exposure occurring in the past occupational situations.

See Figure 3-1.



**Increased**

**Risk of**

**Lung**

**Cancer (X))**

 Figure 3-1. Synergistic Effect for Lung Cancer Between Cigarette

 Smoking and Asbestos Exposure

Lung cancer is rare among nonsmokers, even those who have experienced quite heavy asbestos exposure, so an individual's decision not to smoke is an important defense mechanism.

The American Cancer Society’s *“Cancer Facts & Figures 2010”* publication estimates that 157,300 Americans die annually of lung and bronchus cancer. While more than 400,000 annual deaths are attributed to cigarette smoking, only 5,000 lung cancer deaths per year are believed to be caused by asbestos exposure. Since most of the asbestos-related lung cancers noted are thought to have resulted from workplace exposures where workers wore little or no protective equipment in highly contaminated environments, an asbestos inspector who follows appropriate safety procedures has very little risk of developing asbestos-related lung cancer.

***Mesothelioma***

Mesothelioma is a rare cancer of the mesothelium, a thin tissue layer which lines body cavities and surrounds internal organs. Mesothelioma arises from mesothelial cells or underlying mesenchymal cells in the pleura, pericardium or peritoneum. Mesothelioma which arises in the chest cavity is called pleural mesothelioma. If it develops in the abdominal cavity, it is called peritoneal mesothelioma. Both types of mesothelioma spread rapidly and are always fatal, usually within a year of diagnosis. Smokers do not appear to have a greater risk of mesothelioma than do nonsmokers.

Pleural mesothelioma may begin as a small nodule which seeds the pleural cavity. The tumor involves both layers of mesothelium and can invade the chest wall and lung and spread to the rest of the body via the lymphatic and circulatory systems. Pleural mesothelioma accounts for approximately 85% of all reported cases and is characterized by shortness of breath, chest wall pain and fluid in the chest cavity. The risk of acquiring pleural mesothelioma is higher following exposure to crocidolite than to either chrysotile or amosite asbestos.

Peritoneal mesothelioma, which accounts for the remaining 15% of reported cases, is characterized by abdominal pain and swelling and is almost always attributed to amosite or crocidolite exposure.

The latency period for the development of mesothelioma is usually 20-40 years or more following exposure. The CDC reported 2,704 deaths from mesothelioma in the U.S. in 2005. Most of these deaths occurred in individuals at least 75 years old. The CDC expected the number of deaths from mesothelioma to peak by 2010, but cautioned that the actual numbers of mesothelioma deaths may be underestimated as a result of misdiagnosis.

### *Other Cancers*

Research has shown a clear link between exposure to asbestos and respiratory cancers in humans. The link between exposure to asbestos and other types of cancers is less clear. Some epidemiologic studies suggest an association between gastrointestinal and colorectal cancers and asbestos exposure. Very few studies suggest an elevated risk for cancers of the bladder, brain, kidney, or larynx from asbestos exposure. **Epidemiologic studies do not clearly confirm a relationship between nonrespiratory cancers and asbestos exposure although s**ome research suggests such a relationship.

***Gastrointestinal and Colorectal Cancers***

Studies of asbestos workers suggest that gastrointestinal (esophagus and stomach) and colorectal (colon and rectum) cancers may be associated with asbestos exposure. The evidence is unclear, however.

Some studies showed small increases in the number of asbestos-related deaths from gastrointestinal and colorectal cancers. For example, among 17,800 insulation workers, 99 people died from these cancers, even though the rate in the general population was expected to be 59.4 deaths. Among 2,500 asbestos textile workers, 26 people died from these cancers, but 17.1 deaths were expected. Several other studies have shown similar patterns.

Other mortality studies of asbestos workers, however, found no significantly increased risk for gastrointestinal or colorectal cancers and no causal relationship between workers' exposure to asbestos and gastrointestinal cancer.

Some evidence shows that short-term (acute) oral exposure to asbestos may result in the development of precursor lesions of colon cancer and that long-term (chronic) oral exposure may increase the incidence of gastrointestinal tumors.

Epidemiologic studies have evaluated whether cancer incidence is higher than expected in locations with higher levels of asbestos in drinking water. Most of these studies have detected increases in cancer deaths or incidence rates at one or more tissue sites, primarily in the gastrointestinal tract. Some of these increases were statistically significant. However, the magnitudes of increases in cancer incidence tended to be rather small and may be related to other risk factors such as smoking. Also, these studies were conducted on worker populations with generally higher exposures of all types. Still, only small and inconsistent elevations in cancer rates have been found in such studies. There is relatively little consistency in the observed increases across various studies.

***Bladder, Brain, Kidney, Laryngeal and Other Cancers***

Results of studies of cancers at other human organ sites are also inconclusive, in part because relatively few studies have examined the relationship between asbestos exposure and nonrespiratory cancers. Limited studies have noted excess deaths from, or reported cases of, bladder, brain and kidney cancer. Several epidemiologic studies have reported an increased risk of laryngeal cancer in workers exposed to asbestos.

In contrast, other epidemiologic studies have not found a strong link between increased risk of cancers and asbestos exposure, except for cancers of the lungs and surrounding areas. For example, one analysis concluded that misdiagnosis or chance may be the best explanation for asbestos-related cancer at any other site than the lungs or surrounding areas.

A combined analysis of 55 studies did not find a significant association between occupational exposure to asbestos and laryngeal cancer. Another combined study of asbestos-exposed workers suggested a possible association between asbestos and laryngeal cancer. This same study found no clear association between asbestos exposure and blood-related, lymphatic, reproductive, or urinary cancers.

***Other Abnormalities***

In addition to asbestosis, lung cancer and mesothelioma, inhalation of asbestos fibers is associated with the development of pleural plaques, diffuse pleural thickening, pleuritis and benign lung masses. Such diseases typically develop 20 years or more following initial exposure and their prevalence is related to the duration of exposure.

Pleural plaques are diffuse areas of scar tissue that may form on the mesothelium of the chest cavity or, more rarely, on the pericardium. In individuals free of other lung disease, pleural plaques are asymptomatic and cause no significant lung dysfunction.

Diffuse pleural thickening is a more pronounced scarring of the pleura caused in most cases by adhesions resulting from pleuritis, an inflammation of the pleura. Pleural thickening can cause lung restriction and reduce lung volume.

Benign lung masses can be mistaken for carcinomas and are found in up to 10 percent of workers occupationally exposed to asbestos. Most benign lung masses are sites of inflammation and infolding of the lung tissue associated with adhesive fibrothorax.

Although once regarded as simply indicators of asbestos exposure, fibrotic pleural lesions are now recognized as being capable of reducing lung function and causing disability. Some unconfirmed studies have reported that pleural plaques are associated with a higher incidence of lung and laryngeal cancer and probably mesothelioma. Since pleural disease may be the only indication of asbestos exposure in an individual, the detection of such abnormalities should trigger close medical surveillance.

***Conclusions***

Studies show a strong link between asbestos exposure and the incidence of respiratory cancers. The evidence linking asbestos inhalation exposure to the development of other human cancers is much less conclusive.

***Routes of Exposure***

Through the course of normal human activities, principal exposure routes for asbestos fibers include inhalation, ingestion and skin contact. The following sections provide information regarding the potential hazards from various routes of entry.

***Health Effects Associated with Inhalation***

As previously mentioned, epidemiological investigations have demonstrated that inhalation of asbestos fibers may lead to increased risk of developing one or more diseases or disorders. It is important to recognize that the vast majority of people who have developed asbestosis and asbestos-related lung cancer were workers who were frequently exposed to high concentrations of asbestos fibers on a regular basis with little or no respiratory protection to minimize their risk. In the case of mesothelioma however, some people have developed the disease following brief exposure to asbestos.

***The Respiratory System***

The respiratory system can be significantly affected by inhalation of asbestos fibers. It is divided into two segments, the upper and lower air passages. The upper air passage extends from the nose to the larynx, while the lower air passage extends from the larynx to the terminal bronchioles of the bronchial tube system. Once air has passed through the upper air passages, it moves into the region of the lower air passages via the trachea (windpipe) which traverses the neck. The trachea enters the thorax where it divides into two branches called bronchi. These bronchi lead to the left and right lungs as illustrated in Figure 3-2.



Figure 3-2. The Respiratory System.

Source: The National Heart, Lung, and Blood Institute.

Each bronchus subdivides into many smaller bronchial tubes which, in turn, divide to become even finer bronchioles. The bronchioles end in microscopic air sacs made up of clusters of even tinier sacs called alveoli, which constitute most of the lung tissue. A typical human lung has approximately 750 miles of airways and up to 300 million alveoli with a total alveolar surface area of as much as 800 square feet.

The alveolar walls contain numerous capillaries, the body's tiniest blood vessels. In the lung, the exchange of carbon dioxide for oxygen takes place across the thin membranes of the alveoli and capillaries.

***Defense Mechanisms***

During inhalation the larger particles in the air stream entering the nose are filtered out by the nasal hairs or trapped by the secretions of mucous membranes in the sinus cavities. A second level of defense is the triggering of the cough mechanism which forces particles out of the trachea into the throat area where they can be swallowed or expelled. A third level of physiological defense occurs in the lining of the trachea and bronchial tubes. There, tiny, hair-like, mucus-coated structures known as cilia beat upward in a wave-like motion. This motion, known as the mucociliary escalator, is responsible for moving contaminants from the air passageways to the throat where they are most often swallowed. The final line of defense rests within the alveoli. There, alveolar macrophages (mobile white blood cells) engulf foreign bodies and digest them using strong acids and enzymes. This defense mechanism works well for many inspired agents including small asbestos fibers, but appears ineffective in destroying longer asbestos fibers.

### *Exposure Considerations*

Most asbestos fibers that are inhaled are subsequently expelled, but some can become lodged in the lungs and some can remain there throughout life. Longer fibers, and those that are more durable, such as tremolite and other amphiboles, can contribute to the severity of asbestos-related disorders. Accumulated fibers cause scarring and inflammation which can affect breathing and lead to various diseases.

Significant exposure to any type of asbestos (see Chapter 1 for asbestos types) will increase the risk of lung cancer, mesothelioma and nonmalignant lung and pleural disorders such as asbestosis, pleural plaques, thickening and effusion. Any of the latter disorders can be indications of asbestos exposure and can cause difficulty in breathing. Pleural effusion, an abnormal collection of fluids surrounding the lungs in the chest cavity, can be a warning sign for mesothelioma.

People are more likely to experience asbestos-related disorders when they are exposed to high concentrations of asbestos, are exposed for long periods of time and/or are exposed frequently.

Most cases of asbestosis or lung cancer in workers occur 15 years or more after initial exposure to asbestos. Most cases of mesothelioma are diagnosed 30 years or more after first exposure. Mesothelioma has been diagnosed in asbestos workers, family members and residents who live close to asbestos mines. Health effects from asbestos exposure may continue to progress even after exposure is stopped. The combination of smoking and exposure to asbestos greatly increases the likelihood of lung cancer.

There is an ongoing debate about the relationship of fiber dimension and mineral type with disease causation. For example, some studies indicate that longer fibers are more likely to cause injury than shorter fibers. Additional studies indicate that very short fibers can contribute to injury. Generally, very thick fibers are of lesser concern as they have less chance of penetrating deep into the lung. Scientific consensus is unlikely in the near future because these complex issues involve a myriad of variables and uncertainties, e.g., undetermined exposure levels, multiple pathogenic pathways and individual susceptibilities. Statements made and testimony presented during asbestos-related litigation, where billions of dollars are at stake, also creates confusion about the hazards of asbestos and complicates public perceptions of links between asbestos and disease.

***Inhalation Exposure Pathways***

It is important to recognize that there are asbestos fibers in all the air we breathe. Since the majority of asbestos-related health problems involve the lung and lung region, inhalation of asbestos fibers must be minimized. Individuals may control their exposure to asbestos fibers by properly using respirators and minimizing the time spent in areas of high asbestos fiber concentrations. The various types of inhalation exposure pathways are listed in the following sections.

***Occupational Exposure***

Direct occupational exposure occurs in individuals who work in asbestos mines, mills, landfills, manufacturing and fabricating plants and asbestos abatement sites. (See Table 3-1).

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| **Table 3-1. Asbestos Abatement Fiber Levels** |
| **Work Area** | **Geometric Mean****(f/cc) (50th percentile)** | **Range of Mean Fiber Concentrations Among Abatement Projects (f/cc)** |
| All work areas  | 0.74 | Less than 0.1 - 30.0 |
| Wet removal only  | 0.48 | Less than 0.1 - 12.0 |
| Dry removal only  | 11.9 | 3.7 - 30.0 |

*Source: "Air Sampling at 52 Asbestos Abatement Projects*" (William M. Ewing) referred to in

"Draft Scenarios and Respiratory Protection Recommendations for EPA Inspectors”

(OHSS Memorandum, January 30, 1987).

***Para-occupational Exposure***

Para-occupational exposure occurs outside of the work place. Individuals may encounter asbestos fibers as they are released from deteriorating or disturbed friable asbestos building materials. During the era of more lax occupational procedures when workers routinely brought home asbestos on their work clothing, family members who handled these items had an increased risk of developing asbestos-related disease. In the current era, workers who do not wear protective clothing when working with ACM or ACM debris and who do not decontaminate properly at the end of the work day may expose their families to asbestos fibers.

A 1984 EPA study estimated that over 700,000 of the nation’s three million public and commercial buildings had some type of friable ACM within their structure. In 1991, the Health Effects Institute-Asbestos Research (HEI-AR), which was established to determine for EPA the public's actual exposure to asbestos in such buildings, reported that occupants of public and commercial buildings were exposed to average concentrations of 0.00008 f/cc, an exposure level almost identical to typical urban outdoor concentrations of 0.0001 f/cc.

In general, people merely working in ACM-containing buildings (in a non-maintenance capacity) stand little risk of developing asbestos-related disease or contaminating others.

***Neighborhood Exposure***

Neighborhood exposure is incurred by people who live or work near asbestos mines, manufacturing or fabricating plants, demolition or renovation sites, asbestos landfills or areas where equipment or machinery is sprayed with asbestos-containing fireproofing or insulating material.

***Ambient Background Exposure***

Asbestos exposure from ambient background levels is a result of the release of fibers from the weathering of exposed asbestos-bearing rocks and from the use or weathering of asbestos-containing products such as brake linings, shingles or cladding. Asbestos levels can vary widely depending on the location and the level and condition of asbestos present.

On average, an active adult male breathes approximately 20 cubic meters of air per day. Since airborne asbestos concentrations are expressed in fibers/cubic centimeter of air, for a typical ambient urban area concentration of 0.0001 f/cc (or 100 f/m3), the exposure to asbestos through inhalation is about 2,000 fibers/day.

Because the medical evidence has not yet supported the establishment of a "safe level" of asbestos exposure, the regulatory community has concluded that asbestos release must be kept "to the minimal extent economically feasible."

***Health Effects Associated With Ingestion***

During the early 1980s EPA’s Office of Drinking Water (ODW) closely examined the issue of potential health hazards associated with ingestion of asbestos fibers. The ODW reviewed numerous human and laboratory animal epidemiological studies and, despite the uncertainty of research conclusions linking an increased risk of development of digestive tract cancers to exposure to asbestos fibers, proposed to establish an asbestos fiber limit in drinking water. In January 1991 a limit of 7 million asbestos fibers (greater than 10 µm in length) per liter of drinking water was established in the *National Primary Drinking Water Regulations*.

***Health Effects Associated With Skin Contact***

Although repeated contact with asbestos has been known to cause warts, the dermal route of asbestos fiber entry to the body is not considered a major health issue. However, since ACM contains a variety of substances which may cause skin irritation and rashes, it is always wise to wear protective clothing when working with asbestos materials.

***Theories on Hazard Relationships***

Factors which contribute to the development of asbestos-related disease include the extent of asbestos exposure, fiber type, fiber dimensions, age at exposure and individual susceptibility. At the present time, no means exists to determine conclusively which individuals will or will not develop asbestos-related illnesses following exposure.

***Extent of Exposure***

In general, individuals who experience a lengthy exposure to high levels of airborne asbestos are at a greater risk of developing any of the asbestos-related diseases than individuals who have not been so exposed, with greater exposures associated with greater risk. In addition, in the case of asbestosis, the greater the exposure, the greater the likelihood of developing a severe form of the disease.

A hospital-based case-control study in France published in the *American Journal of Epidemiology (1998; Vol. 148, No. 2: 133-42)* examined the association between occupational exposure to asbestos and pleural mesothelioma. The study found a “clear dose-response relationship between cumulative asbestos exposure and pleural mesothelioma.” The study further stated that “a significant excess of mesothelioma was observed for levels of cumulative exposure that were probably far below the limits adopted in most industrial countries during the 1980s.”

***Asbestos Fiber Type***

All asbestos fiber types have been implicated in the development of asbestos-associated illnesses. There is some evidence, however, that the risk of diseases differs for the various asbestos fiber types, which may be related to relative fiber persistence in the lung associated with the specific chemical composition of each fiber type. Another factor complicating scientific understanding of the role of different fiber types in eliciting disease is the extent of variation in fiber size and shape among fiber types. (See the next paragraph.) Since consensus has not been reached within the medical community regarding the relative risks of amphibole versus serpentine exposure, EPA and OSHA do not distinguish one from the other when regulating asbestos.

***Asbestos Fiber Dimensions***

When disturbed, all forms of asbestos shear longitudinally into finer fibers. Persons exposed to highly processed asbestos have shown some evidence of increased risk of developing asbestos-related diseases. Although exposure to long, thin fibers appears to generate a greater lung cancer risk than exposure to short, thick fibers, there is mixed evidence on the influence of long versus short, thin fibers in the development of mesothelioma.

EPA and OSHA do not regulate asbestos based on fiber size. The phase contrast microscopy (PCM) analytical method for counting air fiber concentrations, however, recognizes all particles greater than 5 µm in length which have a minimum length-to-width (aspect) ratio of 3:1.

***Age at Exposure***

Individuals exposed to asbestos at a young age have a greater risk of developing asbestos-related diseases than similarly exposed adults. It has not been concluded that youngsters are not more sensitive to the effects of asbestos, but simply that they have a longer remaining life at the time of exposure. Since it may take up to 40 or more years for asbestos-related diseases to occur, people exposed during their youth may be more likely to develop asbestos-related diseases than those exposed when they are older.

***Individual Susceptibility***

Another factor influencing the risks from asbestos exposure involves the human body's reaction to asbestos fibers. Why some people who are greatly exposed to airborne asbestos develop an asbestos-related disease while others who are similarly exposed develop a different asbestos disease or none at all, i.e., the mechanism that makes some people more susceptible than others, is a question the scientific/medical community has not been able to answer.

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