Course 750

Introduction to Industrial Hygiene

OSHAcademy
Occupational Safety & Health Training

OSHAcademy Course 750 Study Guide

Introduction to Industrial Hygiene

Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 750.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

OSHAcademy

15220 NW Greenbrier Parkway, Suite 230
Beaverton, Oregon 97006
www.oshatrain.org
instructor@oshatrain.org
+1.888.668.9079

Revised: May 18, 2018

This page intentionally blank

Contents

This page intentionally blank

Course Introduction

What is Industrial Hygiene?

Industrial hygiene is the science of anticipating, recognizing, evaluating, and controlling workplace conditions that may cause workers' injury or illness. Industrial hygienists use environmental monitoring and analytical methods to detect the extent of worker exposure and employ engineering, work practice controls, and other methods to control potential health hazards.

There has been an awareness of industrial hygiene since antiquity. The environment and its relation to worker health were recognized as early as the fourth century BC when Hippocrates noted lead toxicity in the mining industry. In the first century AD, Pliny the Elder, a Roman scholar, perceived health risks to those working with zinc and sulfur. He devised a face mask made from an animal bladder to protect workers from exposure to dust and lead fumes. In the second century AD, the Greek physician, Galen, accurately described the pathology of lead poisoning and also recognized the hazardous exposures of copper miners to acid mists.

In the Middle Ages, guilds worked at assisting sick workers and their families. In 1556 the German scholar, Agricola, advanced the science of industrial hygiene even further when, in his book De Re Metallica, he described the diseases of miners and prescribed preventive measures. The book included suggestions for mine ventilation and worker protection, discussed mining accidents, and described diseases associated with mining occupations such as silicosis.

Industrial hygiene gained further respectability in 1700 when Bernardo Ramazzini, known as the "father of industrial medicine," published in Italy the first comprehensive book on industrial medicine, De Morbis Artificum Diatriba (The Diseases of Workmen). The book contained accurate descriptions of the occupational diseases of most of the workers of his time. Ramazzini greatly affected the future of industrial hygiene because he asserted that occupational diseases should be studied in the work environment rather than in hospital wards.

Industrial hygiene received another major boost in 1743 when Ulrich Ellenborg published a pamphlet on occupational diseases and injuries among gold miners. Ellenborg also wrote about the toxicity of carbon monoxide, mercury, lead, and nitric acid.

In England in the 18th century, Percival Pott, as a result of his findings on the insidious effects of soot on chimney sweepers, was a major force in getting the British Parliament to pass the Chimney-Sweepers Act of 1788. The passage of the English Factory Acts beginning in 1833 marked the first effective legislative acts in the field of industrial safety. The Acts, however, were intended to provide compensation for accidents rather than to control their causes. Later, various other European nations developed workers' compensation acts, which stimulated the adoption of increased factory safety precautions and the establishment of medical services within industrial plants.

In the early 20th century in the United States, Dr. Alice Hamilton led efforts to improve industrial hygiene. She observed industrial conditions first hand and startled mine owners, factory managers, and state officials with evidence there was a correlation between worker illness and their exposure to toxins. She also presented definitive proposals for eliminating unhealthful working conditions.

At about the same time, U.S. federal and state agencies began investigating health conditions in industry. In 1908, the public's awareness of occupationally related diseases stimulated the passage of compensation acts for certain civil employees. States passed the first workers' compensation laws in 1911. And in 1913, the New York Department of Labor and the Ohio Department of Health established the first state industrial hygiene programs. All states enacted such legislation by 1948. In most states, there is some compensation coverage for workers contracting occupational diseases.

The U.S. Congress has passed three landmark pieces of legislation relating to safeguarding workers' health: (1) the Metal and Nonmetallic Mines Safety Act of 1966, (2) the Federal Coal Mine Safety and Health Act of 1969, and (3) the Occupational Safety and Health Act of 1970 (Act). Today, nearly every employer is required to implement the elements of an industrial hygiene and safety, occupational health, or hazard communication program and to be responsive to the Occupational Safety and Health Administration (OSHA) and the Act and its regulations.

Module 1: Industrial Hygiene and OSHA

How Are OSHA and Industrial Hygiene Related?

Under the Act, OSHA develops and sets mandatory occupational safety and health requirements applicable to the more than 6 million workplaces in the U.S. OSHA relies on, among many others, industrial hygienists, or IHs, to evaluate jobs for potential health hazards. More than 40% of OSHA's compliance officers are IHs.

Developing and setting mandatory occupational safety and health standards involves determining the extent of employee exposure to hazards and deciding what is needed to control these hazards, thereby protecting the workers.

Industrial hygienists are trained to anticipate, recognize, evaluate, and recommend controls for environmental and physical hazards that can affect the health and well-being of workers. Important IH responsibilities include:

- Identifying, measuring and analyzing workplace health hazards and exposures (chemical, physical, biological, ergonomic) that can cause sickness, impaired health, or significant discomfort.
- Recommending hazard control strategies to eliminate/reduce hazards and employee exposure to hazards.

Worksite Analysis

To be effective in recognizing and evaluating on-the-job hazards and recommending controls, industrial hygienists must be familiar with the characteristics of all hazards. Major job risks can include air contaminants, and chemical, biological, physical, and ergonomic hazards. A worksite analysis is an essential first step that helps an industrial hygienist determine what jobs and work stations are the sources of these potential and existing hazards.

During the worksite analysis, the industrial hygienist measures and identifies exposures, problem tasks, and risks. The most effective worksite analyses include all jobs, operations, and work activities.

The industrial hygienist inspects, researches, or analyzes how the particular chemicals or physical hazards at that worksite affect worker health. If a situation hazardous to health is discovered, the industrial hygienist recommends the appropriate corrective actions.

Recognizing and Controlling Hazards

Industrial hygienists recognize several primary hazard control strategies to eliminate or reduce hazards and employee exposure. These basic control strategies are further organized into a "Hierarchy of Controls" as follows:

Elimination - removes the hazard. This strategy totally eliminates the hazard from the workplace. This should be the top priority for all safety professionals including industrial hygienists. An example of this strategy includes replacing a hazardous chemical with a totally non-toxic, safe, chemical.

Substitution - reduces the hazard. This strategy should be used if it is not feasible to eliminate the hazard. The idea is to replace the hazard with a less hazardous substitute. An example would be to replace a hazardous chemical with a less hazardous one. There would still be a need for protection like personal protective equipment, but the hazards of exposure would be less serious.

Engineering controls - remove/reduce the hazard through design. This strategy involves the design or redesign of tools, equipment, machinery and facilities so that hazardous chemicals are not needed or that exposure to those hazardous chemicals are not possible. Examples include using equipment that does not require the use of hazardous chemicals in a process or for cleaning. Enclosing work processes or installing general and local ventilation systems might also be used.

It's important to understand that these three strategies are the most effective and primary means to control hazards in the workplace. The next strategies discussed focus in on controlling exposures not hazards.

The Hierarchy of Controls

Administrative controls - eliminate/reduce exposure to hazards. This strategy to helps to reduce exposure by developing and implementing effective training, policies, processes, procedures, practices and safety rules. Examples include scheduling production and worker tasks in ways that minimize exposure levels. The employer might schedule operations with the highest exposure potential during periods when the fewest employees are present.

Work practice controls - eliminate/reduce exposure through safe practices. Following safe procedures while operating production and control equipment, good housekeeping, and safe practices like not eating, drinking, smoking, in regulated areas are all good examples of work practice controls.

Personal Protective Equipment (PPE) - eliminates/reduces exposure through personal barriers. This strategy is generally used in conjunction with the other strategies to reduce exposure. When effective elimination, substitution and engineering controls are not feasible appropriate PPE such as gloves, safety goggles, helmets, safety shoes, and protective clothing may be required. To be effective, PPE must be individually selected, properly fitted and periodically refitted; conscientiously and properly worn; regularly maintained; and replaced as necessary.

It's important to note that administrative/work practices controls and personal protective equipment are the primary control strategies used by IHs to control exposure to health hazards in the workplace.

Module 1 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **Industrial hygienists are trained to anticipate, recognize, evaluate, and recommend controls for environmental and physical hazards.**

    a. True
    b. False

2. **More than _______ of the OSHA compliance officers who inspect America's workplaces are industrial hygienists.**

    a. 10 percent
    b. 25 percent
    c. 40 percent
    d. 65 percent

3. **During the worksite analysis, the industrial hygienist measures and identifies: _______.**

    a. all the employees in the worksite
    b. the distance around the worksite
    c. exposures, problem tasks, and risks
    d. all the worksite production objectives

4. **Mike is an Industrial Hygienist and he is performing a worksite analysis. In order for Mike's worksite analysis to be as effective as possible he should include _______.**

    a. a blueprint of the worksite
    b. all jobs, operations, and work activities
    c. an organizational chart
    d. a worksite communication tree

5. **Mary is an Industrial Hygienist and has just discovered a situation "hazardous to health" at a worksite. What should she do?**

    a. Report the hazard to the police immediately
    b. Report the hazard to OSHA immediately
    c. Recommend the employer should only address the health hazard if they have the money to do so
    d. Recommend the appropriate corrective actions

6. **Industrial hygienists recognize that _______ are the primary means of reducing employee exposure to occupational hazards.**

    a. engineering, work practice, and personal protective equipment
    b. ignoring worksite hazards and providing little oversight
    c. a memo from the Operations Manager at the worksite and harsh discipline
    d. the redesign of every work activity and replacement of every piece of equipment in the worksite

7. **Industrial hygienists recognize several primary hazard control strategies to eliminate or reduce hazards and employee exposure. These basic control strategies are organized into _____.**

    a. the Hierarchy of Controls
    b. three basic levels
    c. the Glazer Pyramid of Priorities
    d. a multi-level system of tactics

8. **Bill is following proper procedures that minimize exposures while operating production and control equipment. This is an example of _______.**

    a. administrative controls
    b. engineering controls
    c. work practice controls
    d. all the above

9. **Samantha is a manager at a worksite. She is scheduling operations with the highest exposure potential during periods when the fewest employees are present. This is an example of _______.**

   a. administrative controls
   b. engineering controls
   c. work practice controls
   d. all the above

Module 2: Air Contaminants

Air contaminants are commonly classified as either particulate or gas and vapor contaminants. The most common particulate contaminants include dusts, fumes, mists, aerosols, and fibers.

Gases are formless fluids that expand to occupy the space or enclosure in which they are confined. Examples are welding gases such as acetylene, nitrogen, helium, and argon; and carbon monoxide generated from the operation of internal combustion engines or by its use as a reducing gas in a heat-treating operation. Another example is hydrogen sulfide which is formed wherever there is decomposition of materials containing sulfur under reducing conditions.

Fumes are formed when material from a volatilized solid condenses in cool air. In most cases, the solid particles resulting from the condensation react with air to form an oxide.

Liquids change into vapors and mix with the surrounding atmosphere through evaporation.

Mists are finely divided liquid suspended in the atmosphere. They are generated by liquids condensing from a vapor back to a liquid or by breaking up a liquid into a dispersed state such as by splashing, foaming or atomizing. **Aerosols** are also a form of a mist characterized by highly respirable, minute liquid particles.

Vapors are the gaseous form of substances that are normally in a solid or liquid state at room temperature and pressure Vapors are formed by evaporation from a liquid or solid and can be found where a worker would clean and/or paint as well as where solvents are used

Dusts are solid particles that are formed or generated from solid organic or inorganic materials by reducing their size through mechanical processes such as crushing, grinding, drilling, abrading or blasting.

Fibers are solid particles whose length is several times greater than their diameter.

Indoor Air Quality

Indoor air quality refers to the presence or absence of air pollutants in buildings. There are many sources of indoor air pollutants. The presence of sources of indoor air pollutants such as tobacco smoke and radon, or by conditions that promote poor indoor air quality such as inadequate ventilation or moisture intrusion that can lead to mold growth, are used as indications of potential health effects.

The quality of indoor air inside offices, schools, and other workplaces is important not only for workers' comfort but also for their health. Poor indoor air quality (IAQ) has been tied to symptoms like headaches, fatigue, trouble concentrating, and irritation of the eyes, nose, throat and lungs. Also, some specific diseases have been linked to specific air contaminants or indoor environments, like asthma with damp indoor environments. In addition, some exposures, such as asbestos and radon, do not cause immediate symptoms but can lead to cancer after many years.

Many factors affect IAQ. These factors include poor ventilation (lack of outside air), problems controlling temperature, high or low humidity, recent remodeling, and other activities in or near a building that can affect the fresh air coming into the building. Sometimes, specific contaminants like dust from construction or renovation, mold, cleaning supplies, pesticides, or other airborne chemicals (including small amounts of chemicals released as a gas over time) may cause poor IAQ.

The right ventilation and building care can prevent and fix IAQ problems.

In approximately 500 indoor air quality investigations in the last decade, the National Institute for Occupational Safety and Health (NIOSH) found the primary sources of indoor air quality problems are:

- Inadequate ventilation 52%
- Contamination from inside building 16%
- Contamination from outside building 10%
- Microbial contamination 5%
- Contamination from building fabric 4%
- Unknown sources 13%

RECOMMENDED VENTILATION RATES

The 62-1989 Standard recommends a minimum of 15 CFM of outdoor air per person for offices (reception areas) and 20 CFM per person for general office space with a moderate amount of smoking. Sixty cubic feet per minute per person is recommended for smoking lounges with local mechanical exhaust ventilation and no air recirculation.

Acute Health Effects of Major Indoor Air Contaminants

Employee complaints can be due to two types of building problems: sick or tight building syndrome and building related illnesses.

Sick building syndrome is a condition associated with complaints of discomfort including headache; nausea; dizziness; dermatitis; eye, nose, throat, and respiratory irritation; coughing; difficulty concentrating; sensitivity to odors; muscle pain; and fatigue. The specific causes of the symptoms are often not known but sometimes are attributed to the effects of a combination of substances or individual susceptibility to low concentrations of contaminants. The symptoms are associated with periods of occupancy and often disappear after the worker leaves the worksite.

Building-related illnesses are those for which there is a clinically defined illness of known etiology and include infections such as legionellosis and allergic reactions such as hypersensitivity diseases and are often documented by physical signs and laboratory findings. A more thorough description of these illnesses can be found in the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines on evaluating bio-aerosols.

Although asbestos and radon have been listed below, acute health effects are not associated with these contaminants. These have been included due to recent concerns about their health effects. The investigator should be aware there may be other health effects in addition to those listed.

Acetic Acid

- Sources: X-ray development equipment, silicone caulking compounds.
- Acute health effects: Eye, respiratory and mucous membrane irritation.

Carbon Dioxide

- Sources: Unvented gas and kerosene appliances, improperly vented devices, processes or operations which produce combustion products, human respiration.
- Acute health effects: Difficulty concentrating, drowsiness, increased respiration rate.

Carbon Monoxide

- Sources: Tobacco smoke, fossil-fuel engine exhausts, improperly vented fossil-fuel appliances.
- Acute health effects: Dizziness, headache, nausea, cyanosis, cardiovascular effects, and death.

Formaldehyde

- Sources: Off-gassing from urea formaldehyde foam insulation, plywood, particle board, and paneling; carpeting and fabric; glues and adhesives; and combustion products including tobacco smoke.
- Acute health effects: Hypersensitive or allergic reactions; skin rashes; eye, respiratory and mucous membrane irritation; odor annoyance.

Nitrogen Oxides

- Sources: Combustion products from gas furnaces and appliances; tobacco smoke, welding, and gas- and diesel-engine exhausts.
- Acute health effects: Eye, respiratory and mucous membrane irritation.

Ozone

- Sources: Copy machines, electrostatic air cleaners, electrical arcing, smog.
- Acute health effects: Eye, respiratory tract, mucous membrane irritation; aggravation of chronic respiratory diseases.

Radon

- Sources: Ground beneath buildings, building materials, and groundwater.
- Acute health effects: No acute health effects are known but chronic exposure may lead to increased risk of lung cancer from alpha radiation.

Volatile Organic Compounds (VOC's): Includes trichloroethylene, benzene, toluene, methyl ethyl ketone, alcohols, methacrylates, acrolein, polycyclic aromatic hydrocarbons, and pesticides.

- Sources: Paints, cleaning compounds, moth-balls, glues, photocopiers, "spirit" duplicators, signature machines, silicone caulking materials, insecticides, herbicides, combustion products, asphalt, gasoline vapors, tobacco smoke, dried out floor drains, cosmetics and other personal products.

- Acute health effects: Nausea; dizziness; eye, respiratory tract, and mucous membrane irritation; headache; fatigue.

Miscellaneous Inorganic Gases: Includes ammonia, hydrogen sulfide, and sulfur dioxide.

- Sources: Microfilm equipment, window cleaners, acid drain cleaners, combustion products, tobacco smoke, blue-print equipment.

- Acute health effects: Eye, respiratory tract, mucous membrane irritation; aggravation of chronic respiratory diseases.

Asbestos

- Sources: Insulation and other building materials such as floor tiles, dry wall compounds, reinforced plaster.

- Acute health effects: Asbestos is normally not a source of acute health effects. However, during renovation or maintenance operations, asbestos may be dislodged and become airborne. Evaluation of employee exposure to asbestos will normally be covered under the OSHA Asbestos standard.

Synthetic Fibers

- Sources: Fibrous glass and mineral wool.

- Acute health effects: Irritation to the eyes, skin and lungs; dermatitis.

Tobacco Smoke

- Sources: Cigars, cigarettes, pipe tobacco.

- Acute health effects: Tobacco smoke can irritate the respiratory system and, in allergic or asthmatic persons, often results in eye and nasal irritation, coughing, wheezing, sneezing, headache, and related sinus problems. People who wear contact lenses often complain of burning, itching, and tearing eyes when exposed to cigarette smoke. 6 Tobacco smoke is a major contributor to indoor air quality problems. Tobacco smoke contains several hundred toxic substances including carbon monoxide, nitrogen dioxide, hydrogen sulfide, formaldehyde, ammonia, benzene, benzo(a)pyrene, tars, and nicotine. Most indoor air particulates are due to tobacco smoke and are in the respirable range.

Microorganisms and Other Biological Contaminants (Microbial): Includes viruses, fungi, mold, bacteria, nematodes, amoeba, pollen, dander, and mites.

- Sources: Air handling system condensate, cooling towers, water damaged materials, high humidity indoor areas, damp organic material and porous wet surfaces, humidifiers, hot water systems, outdoor excavations, plants, animal excreta, animals and insects, food and food products.

- Acute health effects: Allergic reactions such as hypersensitivity diseases (hypersensitivity pneumonitis, humidifier fever, allergic rhinitis, etc.) and infections such as legionellosis are seen. Symptoms include chills, fever, muscle ache, chest tightness, headache, cough, sore throat, diarrhea, and nausea.

Outdoor Air Quality

The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards for six common air pollutants. These commonly found air pollutants (also known as "criteria pollutants") are found all over the United States. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can harm your health and the environment, and cause property damage. Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats. EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels. The set of limits based on human health is called primary standards. Another set of limits intended to prevent environmental and property damage is called secondary standards.

Six Common Outdoor Air Pollutants

Ozone

In the earth's lower atmosphere, ground-level ozone is considered "bad." Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NOx and VOC that help form ozone. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of "bad" ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources.

"Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays.

Particulate Matter

"Particulate matter," also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. EPA groups particle pollution into two categories:

1. *"Inhalable coarse particles,"* such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.

2. *"Fine particles,"* such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes. Nationally and, particularly in urban areas, the majority of CO emissions to ambient air come from mobile sources. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death.

Nitrogen Oxides

Nitrogen dioxide (NO_2) is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NO_x)." Other nitrogen oxides include nitrous acid and nitric acid. While EPA's National Ambient Air Quality Standard covers this entire group of NO_x, NO_2 is the component of greatest interest and the indicator for the larger group of nitrogen oxides. NO_2 forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO_2 is linked with a number of adverse effects on the respiratory system.

Sulfur Dioxide

Sulfur dioxide (SO_2) is one of a group of highly reactive gasses known as "oxides of sulfur." The largest sources of SO_2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%). Smaller sources of SO_2 emissions include industrial processes such as extracting metal from ore, and the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. SO_2 is linked with a number of adverse effects on the respiratory system.

Lead

Lead (Pb) is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been from fuels in on-road motor vehicles (such as cars and trucks) and industrial sources. As a result of EPA's regulatory efforts to remove lead from on-road motor vehicle gasoline, emissions of lead from the transportation sector dramatically declined by 95 percent between 1980 and 1999, and levels of lead in the air decreased by 94 percent between 1980 and 1999. Today, the highest levels of lead in air are usually found near lead smelters. The major sources of lead emissions to the air today are ore and metals processing and piston-engine aircraft operating on leaded aviation gasoline.

Module 2 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **The most common particulate contaminates include _____.**

    a. mists, aerosols, and fibers
    b. fungi and bacteria
    c. dusts and fumes
    d. both A and C

2. **Which answer below is the definition of indoor air quality?**

    a. The presence or absence of mold within a building
    b. The presence or absence of air pollutants in buildings
    c. The presence or absence of humidity found within buildings
    d. The presence or absence of ventilation within a building

3. **Employee complaints regarding air quality often include ____________?**

    a. headache, dizziness and nausea
    b. tiredness and lack of concentration
    c. eye, nose and throat irritation
    d. all the above

4. **The 62-1989 Standard recommends a minimum of ____________ outdoor air per person for offices.**

    a. 5 CFM
    b. 15 CFM
    c. 30 CFM
    d. 60 CFM

5. Sources of Acetic Acid are _________________.

a. processes or operations which produce combustion products
b. unvented gas and kerosene appliances
c. x-ray development equipment, silicone caulking compounds
d. both A and B

6. Acute health effects of Carbon Monoxide poisoning are _________________.

a. dizziness, headache, nausea, cyanosis, cardiovascular effects and death
b. difficulty concentrating, drowsiness and increased respiration rate
c. eye, respiratory and mucous membrane irritation
d. both B and C

7. Miscellaneous inorganic gases include _____.

a. viruses, fungi, mold, bacteria, nematodes, amoeba and pollen
b. fibrous glass and mineral wool
c. ammonia, hydrogen sulfide, sulfur dioxide
d. trichloroethylene, benzene and toluene

8. What are three common outdoor air pollutants?

a. Ozone, particulate matter and carbon monoxide
b. Nitrogen oxides, ammonia and hydrogen sulfide
c. Sulfur dioxide, hydrogen sulfide and lead
d. Ozone, ammonia and lead

Module 3: Chemical Hazards

Introduction

Harmful chemical compounds in the form of solids, liquids, gases, mists, dusts, fumes, and vapors exert toxic effects by inhalation (breathing), absorption (through direct contact with the skin), or ingestion (eating or drinking). Airborne chemical hazards exist as concentrations of mists, vapors, gases, fumes, or solids. Some are toxic through inhalation and some of them irritate the skin on contact; some can be toxic by absorption through the skin or through ingestion, and some are corrosive to living tissue.

The degree of worker risk from exposure to any given substance depends on the nature and potency of the toxic effects and the magnitude and duration of exposure.

Information on the risk to workers from chemical hazards can be obtained from the Safety Data Sheet (SDS) that OSHA'S Hazard Communication Standard requires be supplied by the manufacturer or importer to the purchaser of all hazardous materials. The SDS is a summary of the important health, safety, and toxicological information on the chemical or the mixture's ingredients. Other provisions of the Hazard Communication Standard require that all containers of hazardous substances in the workplace have appropriate warning and identification labels.

Toxic and Hazardous Chemicals

What makes a chemical toxic?

The toxicity of a substance is its ability to cause harmful effects. These effects can strike a single cell, a group of cells, an organ system, or the entire body. A toxic effect may be visible damage, or a decrease in performance or function measurable only by a test. All chemicals can cause harm. When only a very large amount of the chemical can cause damage, the chemical is considered to be practically non-toxic. When a tiny amount is harmful, the chemical is considered to be highly toxic.

The toxicity of a substance depends on three factors: its chemical structure, the extent to which the substance is absorbed by the body and the body's ability to detoxify the substance (change it into less toxic substances) and eliminate it from the body.

Are "toxic" and "hazardous" the same?

No. The toxicity of a substance is the potential of that substance to cause harm, and is only one factor in determining whether a hazard exists. The hazard of a chemical is the practical likelihood that the chemical will cause harm. A chemical is determined to be a hazard depending on the following factors:

- *Toxicity:* how much of the substance is required to cause harm,
- *Route of exposure:* how the substance enters your body,
- *Dose:* how much enters your body,
- *Duration:* the length of time you are exposed,
- *Reaction and interaction:* other substances you are exposed to at the same time, and,
- *Sensitivity:* how your body reacts to the substance compared to other people.

Some chemicals are hazardous because of the risk of fire or explosion. These are important dangers, but are considered to be safety rather than toxic hazards. The factors of a toxic hazard are more fully explained below.

Why are some chemicals more harmful than others?

The most important factor in toxicity is the chemical structure of a substance (i.e., what it is made of), what atoms and molecules it contains and how they are arranged. Substances with similar structures often cause similar health problems. However, slight differences in chemical structure can lead to large differences in the type of health effect produced. For example, silica in one form (amorphous) has little effect on health, and is allowed to be present in the workplace at relatively high levels. After it is heated, however, it turns into another form of silica (crystalline) that causes serious lung damage at levels 200 times lower than amorphous silica.

Routes of Exposure

How can chemicals enter the body?

Exposure normally occurs through inhalation, skin or eye contact, and ingestion.

Inhalation

The most common type of exposure occurs when you breathe a substance into the lungs. The lungs consist of branching airways (called bronchi) with clusters of tiny air sacs (called alveoli) at the ends of the airways. The alveoli absorb oxygen and other chemicals into the bloodstream.

Some chemicals are irritants and cause nose or throat irritation. They may also cause discomfort, coughing, or chest pain when they are inhaled and come into contact with the bronchi (chemical bronchitis). Other chemicals may be inhaled without causing such warning symptoms, but they still can be dangerous.

Sometimes a chemical is present in the air as small particles (dust or mist). Some of these particles, depending on their size, may be deposited in the bronchi and/or alveoli. Many of them may be coughed out, but others may stay in the lungs and may cause lung damage. Some particles may dissolve and be absorbed into the blood stream, and have effects elsewhere in the body.

Skin Contact

The skin is a protective barrier that helps keep foreign chemicals out of the body. However, some chemicals can easily pass through the skin and enter the bloodstream. If the skin is cut or cracked, chemicals can penetrate through the skin more easily. Also, some caustic substances, like strong acids and alkalis, can chemically burn the skin. Others can irritate the skin. Many chemicals, particularly organic solvents, dissolve the oils in the skin, leaving it dry, cracked, and susceptible to infection and absorption of other chemicals.

Eye Contact

Some chemicals may burn or irritate the eye. Occasionally they may be absorbed through the eye and enter the bloodstream. The eyes are easily harmed by chemicals, so any eye contact with chemicals should be taken as a serious incident.

Ingestion

The least common source of exposure in the workplace is swallowing chemicals. Chemicals can be ingested if they are left on hands, clothing or beard, or accidentally contaminate food, drinks or cigarettes. Chemicals present in the workplace as dust, for example, metal dusts such as lead or cadmium, are easily ingested.

Toxicity of Chemicals

Dose: How much is too much?

In general, the greater the amount of a substance that enters your body, the greater is the effect on your body. This connection between amount and effect is called the "dose-response relationship".

For example, organic solvents such as toluene, acetone, and trichloroethylene all affect the brain in the same way, but to different degrees at different doses. The effects of these solvents are similar to those that result from drinking alcoholic beverages. At a low dose, you may feel nothing or a mild, sometimes pleasant ("high") sensation. A larger dose may cause dizziness or headache. With an even larger dose you may become drunk, pass out, or even stop breathing.

When you inhale a toxic chemical, the dose you receive depends on four factors:

1. The level (concentration) of chemical in the air
2. How hard (fast and deep) you are breathing, which depends on your degree of physical exertion
3. How much of the chemical that is inhaled stays in your lungs and is absorbed into your bloodstream?
4. How long the exposure lasts

It is safest to keep exposure to any toxic substance as low as possible. Since some chemicals are much more toxic than others, it is necessary to keep exposure to some substances lower than others. The threshold level is the lowest concentration that might produce a harmful effect. It is different for every chemical. The threshold for one chemical may differ from person to person (see "Sensitivity"). If the concentration of a chemical in the air is kept well below the threshold level, harmful effects probably will not occur. Levels above the threshold are "too much." However, this means only there is a possibility that health effects might occur, not that such effects definitely will occur (see "What are exposure limits?").

Duration: How long is too long?

The longer you are exposed to a chemical, the more likely you are to be affected by it. The dose is still important-at very low levels you may not experience any effects no matter how long you are exposed. At higher concentrations, you may not be affected following a short-term exposure, but repeated exposure over time may cause harm.

Chemical exposure which continues over a long period of time is often particularly hazardous because some chemicals can accumulate in the body or because the damage does not have a chance to be repaired. The combination of dose and duration is called the rate of exposure.

The body has several systems, most importantly the liver, kidneys and lungs, that change chemicals to a less toxic form (detoxify) and eliminate them. If your rate of exposure to a chemical exceeds the rate at which you can eliminate it, some of the chemical will accumulate in your body. For example, if you work with a chemical for eight hours each day, you have the rest of the day (16 hours) to eliminate it from your body before you are exposed again the next day. If your body can't eliminate the entire chemical in 16 hours and you continue to be exposed, the amount in the body will accumulate each day you are exposed. Illness that affects the organs for detoxification and elimination, such as hepatitis (inflammation of the liver), can also decrease their ability to eliminate chemicals from the body.

Accumulation does not continue indefinitely. There is a point where the amount in the body reaches a maximum and remains the same as long as your exposure remains the same. This point will be different for each chemical. Some chemicals, such as ammonia and formaldehyde, leave the body quickly and do not accumulate at all. Other chemicals are stored in the body for long periods. For instance, lead is stored in the bone, calcium is stored in the liver and kidneys, and polychlorinated biphenyls (PCBs) are stored in body fat. There are a few substances, such as asbestos fibers, that, once deposited, remain in the body forever.

Latency: How long does it take for a toxic effect to occur?

The effects of toxic substances may appear immediately or soon after exposure, or they may take many years to appear. Acute exposure is a single exposure or a few exposures. Acute effects are those which occur following acute exposures. Acute effects can occur immediately, or be delayed and occur days or weeks after exposure. Chronic exposure is repeated exposure that occurs over months and years. Chronic effects are those which occur following chronic exposures, and so are always delayed.

A toxic chemical may cause acute effects, chronic effects or both. For example, if you inhale solvents on the job, you may experience acute effects such as headaches and dizziness which go away at the end of the day. Over months, you may begin to develop chronic effects such as liver and kidney damage.

The delay between the beginning of exposure and the appearance of disease caused by that exposure is called the "latency period". Some chronic effects caused by chemicals, such as cancer, have very long latency periods. Cancer has been known to develop as long as 40 years after a worker's first exposure to a cancer-causing chemical.

The length of the latency period for chronic effects makes it difficult to establish the cause-and-effect relationship between the exposure and the illness. Since chronic diseases develop gradually, you may have the disease for some time before it is detected. It is, therefore, important for you and your physician to know what chronic effects might be caused by the substances you use on the job.

Differences between acute and chronic effects

Acute	Chronic
Occurs immediately or soon after exposure (short latency).	Occurs over time or long after exposure (long latency)
Often involves a high exposure (large dose) over a short period.	Often involves low exposures (small doses) over a long period.
Often reversible after exposure stops.	Many effects are not reversible.
Can be minor or severe. For example, a small amount of ammonia can cause throat or eye irritation; larger amounts can be serious or even fatal.	Chronic effects are still unknown for many chemicals. For example, most chemicals have not been tested for cancer or reproductive effects.
Relationship between chemical exposure and symptoms is generally, although not always, obvious.	It may be difficult to establish the relationship between chemical exposure and illness because of the long time delay or latency period.
Knowledge often based on human exposure.	Knowledge often based on animal studies.

Reaction and interaction: What if you're exposed to more than one chemical?

Depending upon the job you have, you may be exposed to more than one chemical. If you are, you need to be aware of possible reactions and interactions between them. A reaction occurs when chemicals combine with each other to produce a new substance. The new substance may have properties different from those of the original substances, and it could be more hazardous. For example, when household bleach and lye (such as a drain cleaner) are mixed together, highly dangerous chlorine gas and hydrochloric acid are formed. The Safety Data Sheet (SDS) for a chemical will often list its potential hazardous reactions and the substances which should not be mixed with it. An employer is required by law to have an SDS for each hazardous substance in the workplace, and make them available for employees on request.

An interaction occurs when exposure to more than one substance results in a health effect different from the effects of either one alone. One kind of interaction is called synergism, a process in which two or more chemicals produce an effect that is greater than the sum of their individual effects. For instance, carbon tetrachloride and ethanol (drinking alcohol) are both toxic to the liver. If you are overexposed to carbon tetrachloride and drink alcohol excessively, the damage to your liver may be much greater than the effects of the two chemicals added together.

Another example of synergism is the increased risk of developing lung cancer caused by exposures to both cigarette smoking and asbestos. By either smoking one pack of cigarettes per day or being heavily exposed to asbestos, you may increase your risk of lung cancer to six times higher than someone who does neither. But if you smoke a pack a day and are heavily exposed to asbestos, your risk may be 90 times higher than someone who does neither.

Another interaction is potentiation, which occurs when an effect of one substance is increased by exposure to a second substance which would not cause that effect by itself. For example, although acetone does not damage the liver by itself, it can increase carbon tetrachloride's ability to damage the liver.

Unfortunately, few chemicals have been tested to determine if interactions with other chemicals occur.

Sensitivity: Are some people more affected than others?

Yes. People vary widely in their sensitivity to the effects of a chemical. Many things determine how an individual will react to a chemical. These include age, sex, inherited traits, diet, pregnancy, state of health and use of medication, drugs or alcohol. Depending on these characteristics, some people will experience the toxic effects of a chemical at a lower (or higher) dose than other people.

People may also become allergic to a chemical. These people have a different type of response than those who are not allergic. This response frequently occurs at a very low dose. Not all chemicals can cause allergic reactions. Substances that are known to cause allergies are called allergens, or sensitizers.

For example, formaldehyde gas is very irritating. Everyone will experience irritation of the eyes, nose, and throat, with tears in the eyes and a sore throat, at some level of exposure. All people will experience irritation if exposed to high enough levels. A person may be more sensitive to formaldehyde and have irritation at low levels of exposure. Formaldehyde also occasionally causes allergic reactions, such as allergic dermatitis, or hives. A few people may be allergic to formaldehyde and develop hives at very low levels, although most people will not get hives no matter how much they are exposed to formaldehyde.

How can toxic substances harm the body?

When a toxic substance causes damage at the point where it first contacts the body, that damage is called a local effect. The most common points at which substances first contact the body are the skin, eyes, nose, throat and lungs. Toxic substances can also enter the body and travel in the bloodstream to internal organs. Effects that are produced this way are called systemic. The internal organs most commonly affected are the liver, kidneys, heart, nervous system (including the brain) and reproductive system.

A toxic chemical may cause local effects, systemic effects, or both. For example, if ammonia gas is inhaled, it quickly irritates the lining of the respiratory tract (nose, throat and lungs). Almost no ammonia passes from the lungs into the blood. Since damage is caused only at the point of initial contact, ammonia is said to exert a local effect. An epoxy resin is an example of a substance with local effects on the skin. On the other hand, if liquid phenol contacts the skin, it irritates the skin at the point of contact (a local effect) and can also be absorbed through the skin, and may damage the liver and kidneys (systemic effects).

Sometimes, as with phenols, the local effects caused by a chemical provide a warning that exposure is occurring. You are then warned that the chemical may be entering your body and producing systemic effects which you can't yet see or feel. Some chemicals, however, do not provide any warning at all, and so they are particularly hazardous. For example, glycol ethers (Cellosolve solvents) can pass through the skin and cause serious internal damage without producing any observable effect on the skin.

What are the different forms of toxic materials?

Toxic materials can take the form of solids, liquids, gases, vapors, dusts, fumes, fibers and mists. How a substance gets into the body and what damage it causes depends on the form or the physical properties of the substance.

A toxic material may take different forms under varying conditions and each form may present a different type of hazard. For example, lead solder in solid form is not hazardous because it is not likely to enter the body. Soldering, however, turns the lead into a liquid, which may spill or come into contact with skin. When the spilled liquid becomes solid again, it may be in the form of small particles (dust) that may be inhaled or ingested and absorbed. If lead is heated to a very high temperature such as when it is welded, a fume may be created; a fume consists of very small particles that are extremely hazardous as they are easily inhaled and absorbed. It is thus important to know what form or forms a given substance takes in the workplace. See below for a description of each of the forms:

Solid

A solid is a material that retains its form, like stone. Most solids are generally not hazardous since they are not likely to be absorbed into the body, unless present as small particles such as dust.

Liquid

A liquid is a material that flows freely, like water. Many hazardous substances are in liquid form at normal temperatures. Some liquids can damage the skin. Some pass through the skin and enter the body and may or may not cause skin damage. Liquids may also evaporate (give off vapors), forming gases which can be inhaled.

Gas

A gas consists of individual chemical molecules dispersed in air, like oxygen, at normal temperature and pressure. Some gases are flammable, explosive, and/or toxic. The presence of a gas may be difficult to detect if it has no color or odor, and does not cause immediate irritation. Such gases, like carbon monoxide, may still be very hazardous.

Vapor

A vapor is the gas form of a substance that is primarily a liquid at normal pressure and temperature. Most organic solvents evaporate and produce vapors. Vapors can be inhaled into the lungs, and in some cases, may irritate the eyes, skin or respiratory tract. Some are flammable, explosive and/or toxic. The term vapor pressure or evaporation rate is used to indicate the tendency for different liquids to evaporate.

Dust

A dust consists of small solid particles in the air. Dusts may be created when solids are pulverized or ground, or when powder (settled dust) becomes airborne. Dusts may be hazardous because they can be inhaled into the respiratory tract. Larger particles of dust are usually trapped in the nose and windpipe (trachea) where they can be expelled, but smaller particles (respirable dust) can reach and may damage the lungs. Some, like lead dust, may then enter the bloodstream through the lungs. Some organic dusts, such as grain dust, may explode when they reach high concentrations in the air.

Fume

A fume consists of very small, fine solid particles in the air which form when solid chemicals (often metals) are heated to very high temperatures, evaporate to vapor, and finally become solid again. The welding or brazing of metal, for example, produces metal fumes. Fumes are hazardous because they are easily inhaled. Many metal fumes can cause an illness called metal fume fever, consisting of fever, chills and aches like the "flu." Inhalation of other metal fumes, such as lead, can cause poisoning without causing metal fume fever.

Fiber

A fiber is a solid particle whose length is at least three times its width. The degree of hazard depends upon the size of the fiber. Smaller fibers such as asbestos, can lodge in the lungs and cause serious harm. Larger fibers are trapped in the respiratory tract; and are expelled without reaching the lung.

Mist

A mist consists of liquid particles of various sizes, which are produced by agitation or spraying of liquids. Mists can be hazardous when they are inhaled or sprayed on the skin. The spraying of pesticides and the machining of metals using metal working fluids are two situations where mists are commonly produced.

What are exposure limits?

Exposure limits are established by health and safety authorities to control exposure to hazardous substances. For example, in Washington State, "Permissible Exposure Limits (PELs)" are set forth in WISHA regulations. By law, Washington employers who use these regulated chemicals must control employee exposures to be below the PELs for these substances. Permissible exposure limits usually represent the maximum amount (concentration) of a chemical that can be present in the air without presenting a health hazard.

Permissible exposure limits may not always be completely protective, for the following reasons:

1. Although exposure limits are usually based on the best available information, this information, particularly for chronic (long-term) health effects, may be incomplete. Often we learn about chronic health effects only after workers have been exposed to a chemical for many years, and then as new information is learned, the exposure limits are changed.

2. Exposure limits are set to protect most workers. However, there may be a few workers who will be affected by a chemical at levels below these limits (refer to "Sensitivity" in Module 3.6). Employees performing extremely heavy physical exertion breathe in more air and more of a chemical, and so may absorb an excessive amount.

3. Exposure limits do not take into account chemical interactions. When two or more chemicals in the workplace have the same health effects, industrial hygienists use a mathematical formula to adjust the exposure limits for those substances in that workplace. This formula applies to chemicals that have additive effects, but not to those with synergistic or potentiating effects (refer to "Reaction and Interaction" in Module 3.6).

4. Exposure limits usually apply to the concentration of a chemical in the air, and are established to limit exposure by inhalation. Limiting the concentration in air may not prevent excessive exposure through skin contact or ingestion. Chemicals that may produce health effects as a result of absorption through the skin have an "S" designation next to their numerical value in the PEL table. Workers exposed to these chemicals must be provided with protective clothing to wear when overexposure through the skin is possible. Some chemicals, like lead and cadmium in dust form, may be ingested through contamination of hands, hair, clothes, food and cigarettes.

How can exposure be measured and monitored?

When toxic chemicals are present in the workplace, your exposure can be determined by measuring the concentration of a given chemical in the air and the duration of exposure. This measurement is called air or environmental monitoring or sampling and is usually done by industrial hygienists, using various types of instruments. The air is collected from your breathing zone (the air around your nose and mouth) so that the concentrations measured will accurately reflect the concentration you are inhaling. The exposure levels calculated from this monitoring can then be compared to the Permissible Exposure Limit (PEL) for that chemical.

Environmental Monitoring

Environmental monitoring is the most accurate way to determine your exposure to most chemicals. However, for chemicals that are absorbed by routes other than inhalation, such as through the skin and by ingestion, air monitoring may underestimate the amount of chemical you absorb. For these and some other chemicals, the levels of the chemical (or its breakdown products) in the body can sometimes be measured in the blood, urine or exhaled air. Such testing is called biological monitoring, and the results may give an estimate of the actual dose absorbed into the body. For one substance, lead, biological monitoring is required by law when air monitoring results are above a certain level. The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended the exposure limits for biological monitoring for a small number of chemicals. These are called Biological Exposure Indices (BEIs) and are published together with TLVs.

Practical clues to exposure

Odor

If you smell a chemical, you are inhaling it. However, some chemicals can be smelled at levels well below those that are harmful, so that detecting an odor does not mean that you are inhaling harmful amounts. On the other hand, if you cannot smell a chemical, it may still be present. Some chemicals cannot be smelled even at levels that are harmful.

The odor threshold is the lowest level of a chemical that can be smelled by most people. If a chemical's odor threshold is lower than the amount that is hazardous, the chemical is said to have good warning properties. One example is ammonia. Most people can smell it at 5 ppm, below the PEL of 25 ppm. It is important to remember that for most chemicals, the odor thresholds vary widely from person to person. In addition, some chemicals, like hydrogen sulfide, cause you to rapidly lose your ability to smell them (called olfactory fatigue). With these cautions in mind, knowing a chemical's odor threshold may serve as rough guide to your exposure level.

Don't depend on odor to warn you. Remember, your sense of smell may be better or worse than average, some very hazardous chemicals have no odor (carbon monoxide), some chemicals of low toxicity have very strong odors (mercaptans added to natural gas), and others produce olfactory fatigue.

Taste

If you inhale or ingest a chemical, it may leave a taste in your mouth. Some chemicals have a particular taste, which may be mentioned in an SDS.

Particles in Nose or Throat

If you cough up mucous (sputum or phlegm) with particles in it, or blow your nose and see particles on your handkerchief, then you have inhaled some chemical in particle form. Unfortunately, most particles which are inhaled into the lungs are too small to see.

Settled Dust or Mist

If chemical dust or mist is in the air, it will eventually settle on work surfaces or on your skin, hair and clothing. If settled dust or mist is visible, it is possible you inhaled some of this chemical while it was in the air.

Immediate Symptoms

If you or your co-workers experience symptoms known to be caused by a chemical during or shortly after its use, you may have been overexposed. Symptoms might include tears in your eyes; a burning sensation of skin, nose, or throat; a cough; dizziness or a headache.

How can exposures be reduced?

Exposures can be reduced through implementation of training (knowledge) and engineering controls.

Knowledge

Everyone who works with toxic substances should know the names, toxicity and other hazards of the substances they use. Employers are required by law to provide this information, along with training in how to use toxic substances safely. A worker may obtain information about a chemical's composition, physical characteristics, and toxicity from the Safety Data Sheet (SDS).

Engineering controls

Limiting exposure to hazards at the source is the preferred way to protect workers. The types of engineering controls used to reduce this exposure to hazards, in order of effectiveness, are:

Substitution

Substitution is using a less hazardous substance. But before choosing a substitute, carefully consider its physical and health hazards. For example, mineral spirits (Stoddard Solvent) is less of a health hazard than perchloroethylene for dry cleaning, but is more of a fire hazard and an air pollutant.

Enclosure/Isolation

Process or equipment enclosure is the isolation of the source of exposure, often through automation. This completely eliminates the routine exposure of workers. For example, handling of radioactive materials is often done by mechanical arms or robots.

Local exhaust ventilation is a hood or air intake at or over the source of exposure to capture or draw contaminated air from its source before it spreads into the room and into your breathing zone.

Ventilation

General or dilution ventilation is continual replacement and circulation of fresh air sufficient to keep concentrations of toxic substances diluted below hazardous levels. However, concentrations will be highest near the source, and overexposure may occur in this area. If the dilution air is not well mixed with the room air, pockets of high concentrations may exist.

Personal Protective Equipment

Personal protective equipment (respirators, gloves, goggles and aprons) should be used only when engineering controls are not possible or are not sufficient to reduce exposure.

Respiratory Protective Equipment

Respiratory protective equipment consists of devices that cover the mouth and nose to prevent substances in the air from being inhaled. A respirator is effective only when used as part of a comprehensive program established by the employer, which includes measurement of concentrations of all hazardous substances, selection of the proper respirator, training the worker in its proper use, fitting of the respirator to the worker, maintenance, and replacement of parts when necessary.

Protective Clothing

Protective clothing includes gloves, aprons, goggles, boots, face shields, and any other materials worn as protection. It should be made of material designed to resist penetration by the particular chemical being used. Such material may be called impervious to that chemical. The manufacturer of the protective clothing usually can provide some information regarding the substances that are effectively blocked.

Barrier Creams

Barrier creams are special lotions used to coat the skin and prevent chemicals from reaching it. They may be helpful when the type of work prevents the use of gloves. However, barrier creams are not recommended as substitutes for gloves. Cosmetic skin creams and lotions (such as moisturizing lotion) are not barrier creams.

Module 3 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **The degree of worker risk from exposure to any given substance depends on the _______.**

    a. nature and potency of the non-toxic effects
    b. nature and potency of the toxic effects and the magnitude and duration of exposure
    c. magnitude and duration of toxic effects
    d. magnitude and duration of non-toxic effects

2. **Bob is an employee for ABC Inc. Part of his job consists of handling hazardous chemicals. Where can Bob look up information regarding the risks involved with working with chemical hazards?**

    e. Safety Data Sheet (SDS)
    a. Chemical Composition Manual
    b. Employer Job Postings
    c. Employer Policy Manual

3. **When a tiny amount of a chemical is harmful, the chemical is considered to be highly toxic.**

    a. True
    b. False

4. **How can chemicals enter the body?**

    a. Inhalation, and skin contact
    b. Eye contact, and ingestion
    c. Through personal protective equipment
    d. Both a and b

5. **What is the "dose-response relationship"?**

    a. The greater someone's sensitivity to a chemical, the greater is the effect on their body
    b. The greater the toxicity of a substance the less the effect it has on your body
    c. The less a substance enters your body, the greater is the effect on your body
    d. The greater the amount of a substance that enters your body, the greater is the effect on your body

6. **While cooking at a fast food restaurant the employees wear latex gloves for sanitation purposes. None of the employees have physical reactions to the gloves except for Mary. Mary would be considered _______ to latex.**

    a. latent
    b. resistant
    c. sensitive
    d. both a and b

7. **Toxic substances can enter the body and travel in the bloodstream to internal organs. This is called ______.**

    a. a local effect
    b. a systemic effect
    c. a non-local effect
    d. a non-systemic effect

8. **Exposure limits are _______.**

    a. established by employers to control exposure to hazardous substances.
    b. established by health and safety authorities to control exposure to hazardous substances
    c. established by health and safety authorities to increase exposure to hazardous substances
    d. established by employers to reduce exposure to hazardous substances

Module 4: Biological Hazards

Introduction

Biological hazards include bacteria, viruses, fungi, and other living organisms that can cause acute and chronic infections by entering the body either directly or through breaks in the skin. Occupations that deal with plants or animals or their products or with food and food processing may expose workers to biological hazards. Laboratory and medical personnel also can be exposed to biological hazards. Any occupations that results in contact with bodily fluids pose a risk to workers from biological hazards.

In occupations where animals are involved, biological hazards are dealt with by preventing and controlling diseases in the animal population; as well as properly caring for and handling infected animals. Also, effective personal hygiene, particularly proper attention to minor cuts and scratches especially on the hands and forearms, helps keep worker risks to a minimum.

In occupations where there is potential exposure to biological hazards, workers should practice proper personal hygiene; particularly hand washing. Hospitals should provide proper ventilation, proper personal protective equipment such as gloves and respirators, adequate infectious waste disposal systems, and appropriate controls including isolation in instances of particularly contagious diseases such as tuberculosis.

Biological Agents

Biological agents include bacteria, viruses, fungi, other microorganisms and their associated toxins. They have the ability to adversely affect human health in a variety of ways, ranging from relatively mild, allergic reactions to serious medical conditions, even death. These organisms are widespread in the natural environment; they are found in water, soil, plants, and animals. Because many microbes reproduce rapidly and require minimal resources for survival, they are a potential danger in a wide variety of occupational settings.

This page provides a starting point for technical and regulatory information about some of the most virulent and prevalent biological agents.

Anthrax

Anthrax is an acute infectious disease caused by a spore-forming bacterium called Bacillus anthracis. It is generally acquired following contact with anthrax-infected animals or anthrax-contaminated animal products.

Avian Flu

Avian influenza is a highly contagious disease of birds which is currently epidemic amongst poultry in Asia. Despite the uncertainties, poultry experts agree that immediate culling of infected and exposed birds is the first line of defense for both the protection of human health and the reduction of further losses in the agricultural sector.

Bloodborne Pathogens and Needlestick Prevention

OSHA estimates 5.6 million workers in the health care industry and related occupations are at risk of occupational exposure to bloodborne pathogens, including human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and others.

Botulism

Cases of botulism are usually associated with consumption of preserved foods. However, botulism toxins are currently among the most common compounds explored by terrorists for use as biological weapons.

Foodborne Disease

Foodborne illnesses are caused by viruses, bacteria, parasites, toxins, metals, and prions (microscopic protein particles). Symptoms range from mild gastroenteritis to life-threatening neurologic, hepatic, and renal syndromes.

Hantavirus

Hantaviruses are transmitted to humans from the dried droppings, urine, or saliva of mice and rats. Animal laboratory workers and persons working in infested buildings are at increased risk to this disease.

Legionnaires' disease

Legionnaires' disease is a bacterial disease commonly associated with water-based aerosols. It is often the result of poorly maintained air conditioning cooling towers and potable water systems.

Mold

Molds produce and release millions of spores small enough to be air-, water-, or insect-borne which may have negative effects on human health including allergic reactions, asthma, and other respiratory problems.

Plague

The World Health Organization reports 1,000 to 3,000 cases of plague every year. A bioterrorist release of plague could result in a rapid spread of the pneumonic form of the disease, which could have devastating consequences.

Ricin

Ricin is one of the most toxic and easily produced plant toxins. It has been used in the past as a bioterrorist weapon and remains a serious threat.

Severe Acute Respiratory Syndrome (SARS)

Severe acute respiratory syndrome (SARS) is an emerging, sometimes fatal, respiratory illness. According to the Centers for Disease Control and Prevention (CDC), the most recent human cases of SARS were reported in China in April 2004 and there is currently no known transmission anywhere in the world.

Smallpox

Smallpox is a highly contagious disease unique to humans. It is estimated that no more than 20 percent of the population has any immunity from previous vaccination.

Tularemia

Tularemia is also known as "rabbit fever" or "deer fly fever" and is extremely infectious. Relatively few bacteria are required to cause the disease, which is why it is an attractive weapon for use in bioterrorism.

Viral Hemorrhagic Fevers (VHFs)

Along with smallpox, anthrax, plague, botulism, and tularemia, hemorrhagic fever viruses are among the six agents identified by the Centers for Disease Control and Prevention (CDC) as the most likely to be used as biological weapons. Many VHFs can cause severe, life-threatening disease with high fatality rates.

Possible Risks and Suggested Measures

Occupations at Risk	Hazards/Risks	Preventative Measures
Food (cheese, yogurt, salami) or food additive production and bakeries	• Molds/yeasts, bacteria and mites cause allergies. • Organic dusts of grain, milk powder or flour contaminated with biological agents. • Toxins such as botulinustoxins or aflatoxins	Closed processes Avoid aerosol formation Separate contaminated work areas Appropriate hygiene measures
Health Care	• Several viral and bacterial infections such as HIV, hepatitis, or tuberculosis. • Needlestick injuries	Safe handling of infectious specimens, sharps waste, contaminated linen and other materials. Safe handling and cleaning of blood spills and other body fluids. Adequate protective equipment, gloves, clothing, glasses. Appropriate hygienic measures

Laboratories	• Infections and allergies when handling microorganisms and cell cultures (human tissues.) • Accidental spills and needlestick injuries.	Microbiological safety cabinets Dust and aerosol-reducing measures. Safe handling and transport of samples. Appropriate personal protection and hygiene measures. Decontamination and emergency measures for spills. Restricted access. Biosafety labels.
Agriculture Forestry Horticulture Animal food and fodder production	• Bacteria, fungi, mites and viruses transmitted from animals, parasites and ticks. • Respiratory problems due to microorganisms and mites in organic dusts of grain, mild powder, flour, spices. • Specific allergic diseases like farmer's lung and bird breeder's lung.	Dust and aerosol-reducing measures Avoid contact with contaminated animal or equipment Protection against animal bites and stings Preservatives for fodder Cleaning and maintenance

Metal processing industry Wood processing industry	- Skin problems due to bacteria - Bronchial asthma due to molds/yeasts in circulating fluids in industrial processes such as grinding, pulp factories' and metal and stone cutting fluids.	Local exhaust ventilation Regular maintenance, filtering and decontamination of fluids and machinery. Skin protection Appropriate hygiene measures
Working areas with air conditioning systems and high humidity (textile industry, print industry and paper production)	- Allergies and respiratory disorders due to molds/yeasts. - Legionnaires disease	Dust- and aerosol-reducing measures. Regular maintenance of ventilation, machinery and work areas. Restrict number of workers. Maintaining high hot (tap) water temperatures.
Archives Museums Libraries	Molds/yeasts and bacteria cause allergies and respiratory disorders	Dust- and aerosol-reduction. Decontamination Adequate personal protective equipment

Building and construction industry Processing of natural materials like clay, straw and reed Redevelopment of buildings	Molds and bacteria due to deterioration of building materials	Dust- and aerosol-reducing measures Appropriate personal protection and hygiene measures

Module 4 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **Biological hazards include _______ that can cause acute and chronic infections.**

    a. Formaldehyde, Radon, and pesticides
    b. Carbon Dioxide, Nitrogen Oxides, and Ozone
    c. bacteria, viruses, fungi, and other living organisms
    d. both a and b

2. **In occupations where there is potential exposure to biological hazards, workers should practice proper personal hygiene, particularly _______.**

    a. scrubbing their face
    b. hand washing
    c. combing their hair
    d. taking showers

3. **_______ is an acute infectious disease caused by a spore-forming bacterium called Bacillus anthracis.**

    a. Botulism
    b. Avian Flu
    c. Ricin
    d. Anthrax

4. **_______ are currently among the most common compounds explored by terrorists for use as biological weapons.**

    a. Botulinum toxins
    b. Bacillus anthracis
    c. Hantavirus
    d. Prions

5. **_______ are caused by viruses, bacteria, parasites, toxins, metals, and prions (microscopic protein particles). Symptoms range from mild gastroenteritis to life-threatening neurologic, hepatic, and renal syndromes.**

   a. Molds
   b. Foodborne Illnesses
   c. Ricins
   d. Bloodborne pathogens

6. **_______ is one of the most toxic and easily produced plant toxins. It has been used in the past as a bioterrorist weapon and remains a serious threat.**

   a. Ricin
   b. Hantavirus
   c. Anthrax
   d. Botulism

7. **_______ is also known as "rabbit fever" or "deer fly fever" and is extremely infectious. Relatively few bacteria are required to cause the disease, which is why it is an attractive weapon for use in bioterrorism.**

   a. Ricin
   b. Hantavirus
   c. Anthrax
   d. Tularemia

8. **John works in a library. What are some of the risks/hazards he faces at work?**

   a. Needlestick injuries
   b. Respiratory problems due to microorganisms and mites in organic dusts of grain, mild powder, flour, and spices.
   c. Molds/yeasts and bacteria that can cause allergies and respiratory disorders.
   d. Legionnaires disease

Module 5: Physical Hazards

Physical hazards that employees in the workplace face include excessive levels of ionizing and non-ionizing radiation, noise, vibration, illumination, and temperature.

Protection Strategies

Ionizing Radiation. In occupations where there is exposure to ionizing radiation, time, distance, and shielding are important tools in ensuring worker safety. Danger from radiation increases with the amount of time one is exposed to it; hence, the shorter the time of exposure the smaller the radiation danger.

Distance also is a valuable tool in controlling exposure to both ionizing and non-ionizing radiation. Radiation levels from some sources can be estimated by comparing the squares of the distances between the worker and the source. For example, at a reference point of 10 feet from a source, the radiation is 1/100 of the intensity at 1 foot from the source.

Shielding also is a way to protect against radiation. The greater the protective mass between a radioactive source and the worker, the lower the radiation exposure.

Non-ionizing Radiation. Non-ionizing radiation also is dealt with by shielding workers from the source. Sometimes limiting exposure times to non-ionizing radiation or increasing the distance is not effective. Laser radiation, for example, cannot be controlled effectively by imposing time limits. An exposure can be hazardous that is faster than the blinking of an eye. Increasing the distance from a laser source may require miles before the energy level reaches a point where the exposure would not be harmful.

Noise. Noise, another significant physical hazard, can be controlled by various measures. Noise can be reduced using engineering controls like:

- installing equipment and systems that have been engineered, designed, and built to operate quietly;
- enclosing or shielding noisy equipment;
- making certain that equipment is in good repair and properly maintained with all worn or unbalanced parts replaced;
- mounting noisy equipment on special mounts to reduce vibration; and

- installing silencers, mufflers, or baffles;
- substituting quiet work methods for noisy ones like welding parts together rather than riveting them;
- treating floors, ceilings, and walls with acoustical material can reduce reflected or reverberant noise;
- erecting sound barriers at adjacent work stations around noisy operations.

It is also possible to reduce noise exposure through administrative and work practice controls like:

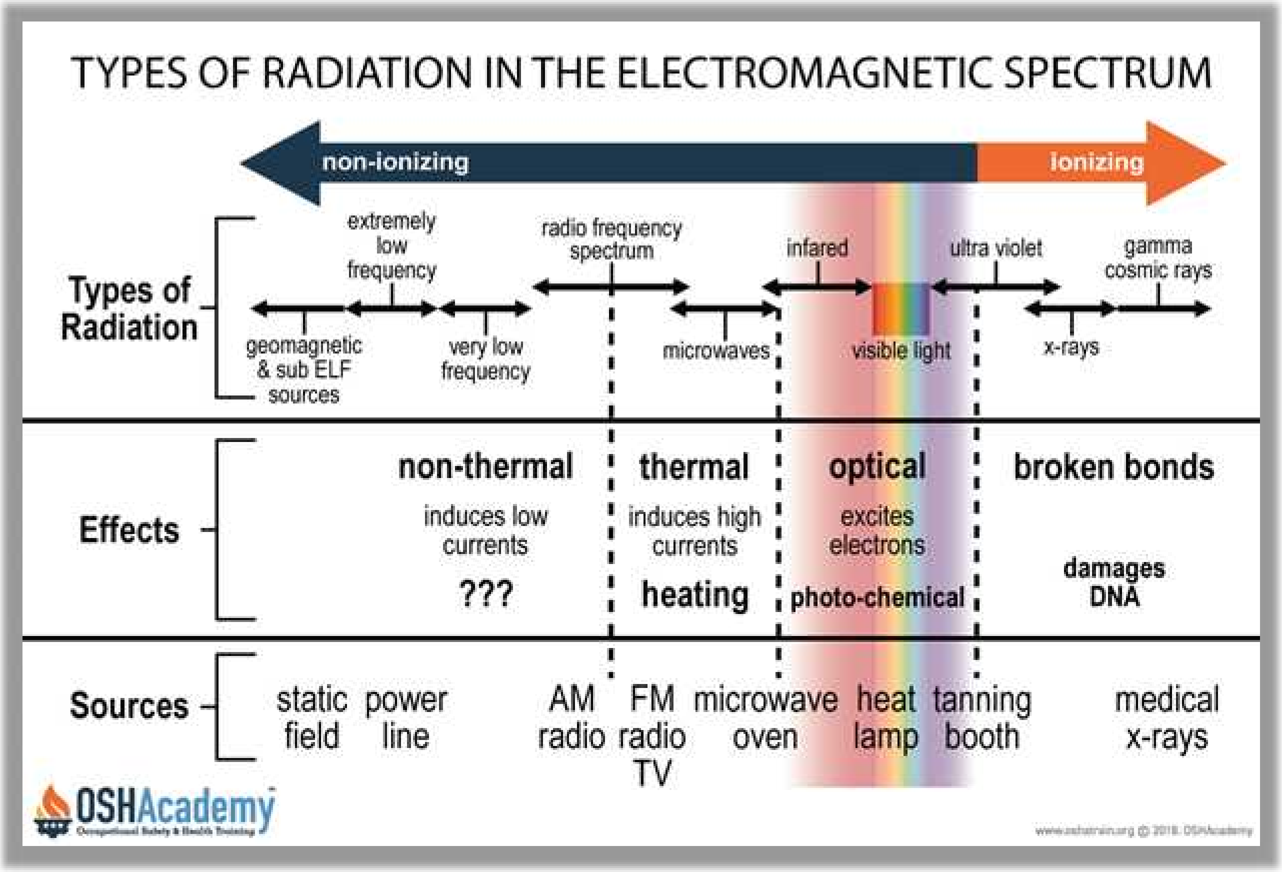
- increasing the distance between the source and the receiver,
- isolating workers in acoustical booths,
- limiting workers' exposure time to noise, and
- providing hearing protection.

OSHA requires that workers in noisy surroundings be periodically tested as a precaution against hearing loss.

Radiant heat. Another physical hazard, radiant heat exposure in factories such as steel mills, can be controlled by installing reflective shields and by providing protective clothing.

Well discuss these hazards and protective measures in more detail in the following sections.

Ionizing & Non-Ionizing Radiation



Radiation having a wide range of energies form the electromagnetic spectrum, which is illustrated above. The spectrum has two major divisions:

- Non-ionizing radiation
- Ionizing radiation

Nonionizing Radiation

Non-ionizing radiation ranges from extremely low frequency radiation, shown on the far left through the audible, microwave, and visible portions of the spectrum into the ultraviolet range.

Extremely low-frequency radiation has very long wave lengths (on the order of a million meters or more) and frequencies in the range of 100 Hertz or cycles per second or less. Radio frequencies have wave lengths of between 1 and 100 meters and frequencies in the range of 1 million to 100 million Hertz. Microwaves that we use to heat food have wavelengths that are about 1 hundredth of a meter long and have frequencies of about 2.5 billion Hertz.

We take advantage of the properties of non-ionizing radiation for common tasks:

- microwave radiation-- telecommunications and heating food
- infrared radiation --infrared lamps to keep food warm in restaurants
- radio waves-- broadcasting

Ionizing Radiation

Radiation that falls within the ionizing radiation" range has enough energy to remove tightly bound electrons from atoms, thus creating ions. This is the type of radiation that people usually think of as 'radiation.' We take advantage of its properties to generate electric power, to kill cancer cells, and in many manufacturing processes.

There are three main kinds of ionizing radiation:

- Alpha particles, which include two protons and two neutrons.
- Beta particles, which are essentially electrons.
- Gamma rays and x-rays, which are pure energy (photons).

Higher frequency ultraviolet radiation begins to have enough energy to break chemical bonds. X-ray and gamma ray radiation, which are at the upper end of magnetic radiation have very high frequency --in the range of 100 billion billion Hertz--and very short wavelengths--1 million millionth of a meter. Radiation in this range has extremely high energy. It has enough energy to strip off electrons or, in the case of very high-energy radiation, break up the nucleus of atoms.

Noise

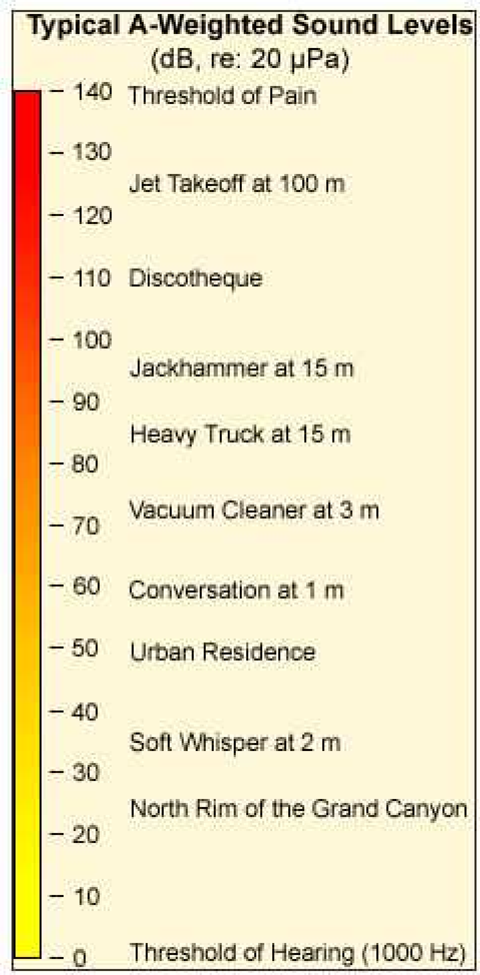
Every year, millions of people in the United States are exposed to hazardous noise at work. Noise-related hearing loss has been listed as one of the most prevalent occupational health concerns in the United States for many years.

Exposure to high levels of noise can cause permanent hearing loss. Neither surgery nor a hearing aid can help correct this type of hearing loss. Short term exposure to loud noise can also cause a temporary change in hearing (your ears may feel stuffed up) or a ringing in your ears (tinnitus). These short-term problems may go away within a few minutes or hours after leaving the noisy area. However, repeated exposures to loud noise can lead to permanent tinnitus and/or hearing loss.

Loud noise can also create physical and psychological stress, reduce productivity, interfere with communication and concentration, and contribute to workplace accidents and injuries by making it difficult to hear warning signals. Noise-induced hearing loss limits your ability to hear high frequency sounds, understand speech, and seriously impairs your ability to communicate. The effects of hearing loss can be profound, as hearing loss can interfere with your ability to enjoy socializing with friends, playing with your children or grandchildren, or participating in other social activities you enjoy. It can eventually lead to psychological and social isolation.

How does the ear work?

When sound waves enter the outer ear, the vibrations impact the ear drum and are transmitted to the middle and inner ear. In the middle ear three small bones called the malleus (or hammer), the incus (or anvil), and the stapes (or stirrup) amplify and transmit the vibrations generated by the sound to the inner ear. The inner ear contains a snail-like structure called the cochlea which is filled with fluid and lined with cells with very fine hairs. These microscopic hairs move with the vibrations and convert the sound waves into nerve impulses - the result is the sound we hear.



Exposure to loud noise can destroy these hair cells and cause hearing loss!

What are the warning signs that your workplace may be too noisy?

Noise may be a problem in your workplace if:

- You hear ringing or humming in your ears when you leave work.
- You have to shout to be heard by a coworker an arm's length away.
- You experience temporary hearing loss when leaving work.

How loud is too loud?

Noise is measured in units of sound pressure levels called decibels, named after Alexander Graham Bell, using A-weighted sound levels (dBA). The A-weighted sound levels closely match the perception of loudness by the human ear. Decibels are measured on a logarithmic scale which means that a small change in the number of decibels results in a huge change in the amount of noise and the potential damage to a person's hearing.

OSHA sets legal limits on noise exposure in the workplace. These limits are based on a worker's time weighted average over an 8-hour day. With noise, OSHA's permissible exposure limit (PEL) is 90 dBA for all workers for an 8-hour day. The OSHA standard uses a 5 dBA exchange rate. This means that when the noise level is increased by 5 dBA, the amount of time a person can be exposed to a certain noise level to receive the same dose is cut in half.

The National Institute for Occupational Safety and Health (NIOSH) has recommended all worker exposures to noise should be controlled below a level equivalent to 85 dBA for eight hours to minimize occupational noise induced hearing loss. NIOSH has found that significant noise-induced hearing loss occurs at the exposure levels equivalent to the OSHA PEL based on updated information obtained from literature reviews. NIOSH also recommends a 3 dBA exchange rate so that every increase by 3 dBA doubles the amount of the noise and halves the recommended amount of exposure time.

Here's an example: OSHA allows 8 hours of exposure to 90 dBA but only 2 hours of exposure to 100 dBA sound levels. NIOSH would recommend limiting the 8-hour exposure to less than 85 dBA. At 100 dBA, NIOSH recommends less than 15 minutes of exposure per day.

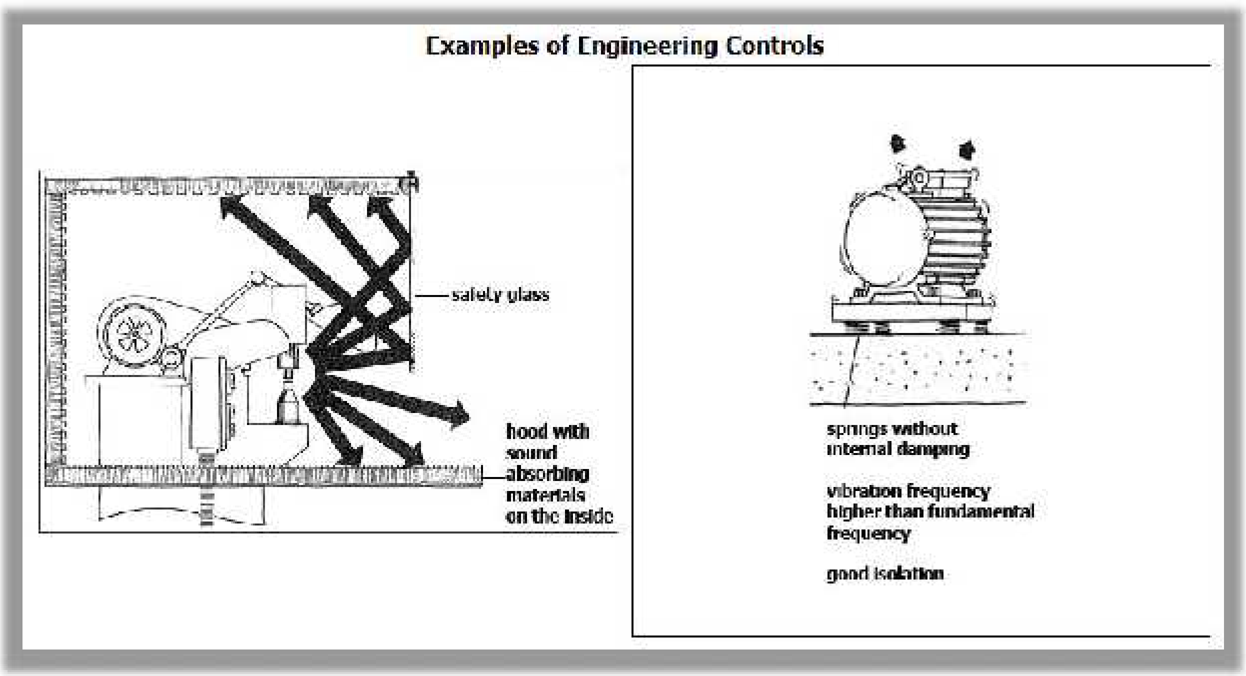
In 1981, OSHA implemented new requirements to protect all workers in general industry (e.g. the manufacturing and the service sectors) for employers to implement a Hearing Conservation Program where workers are exposed to a time weighted average noise level of 85 dBA or higher over an 8-hour work shift. Hearing Conservation Programs require employers to measure noise levels, provide free annual hearing exams and free hearing protection, provide training, and conduct evaluations of the adequacy of the hearing protectors in use unless changes to tools, equipment and schedules are made so that they are less noisy and worker exposure to noise is less than the 85 dBA.

What can be done to reduce the hazard from noise?

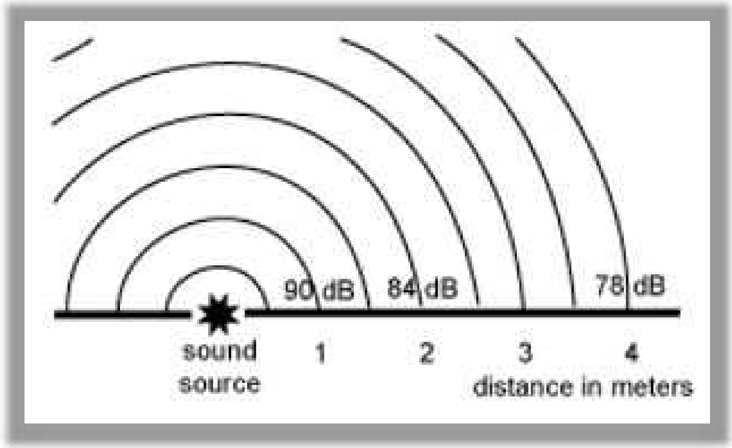
Noise controls are the first line of defense against excessive noise exposure. The use of these controls should aim to reduce the hazardous exposure to the point where the risk to hearing is eliminated or minimized. With the reduction of even a few decibels, the hazard to hearing is reduced, communication is improved, and noise-related annoyance is reduced. There are several ways to control and reduce worker exposure to noise in a workplace. Engineering controls that reduce sound exposure levels are available and technologically feasible for most noise sources. Engineering controls involve modifying or replacing equipment, or making related physical changes at the noise source or along the transmission path to reduce the noise level at the worker's ear. In some instances the application of a relatively simple engineering noise control solution reduces the noise hazard to the extent that further requirements of the OSHA Noise standard (e.g., audiometric testing (hearing tests), hearing conservation program, provision of hearing protectors, etc...) are not necessary.

Examples of inexpensive, effective engineering controls include some of the following:

- Choose low-noise tools and machinery (e.g., Buy Quiet Roadmap (NASA)).
- Maintain and lubricate machinery and equipment (e.g., oil bearings).
- Place a barrier between the noise source and employee (e.g., sound walls or curtains).
- Enclose or isolate the noise source.



Administrative controls are changes in the workplace that reduce or eliminate the worker exposure to noise. Examples include:



- Operating noisy machines during shifts when fewer people are exposed.
- Limiting the amount of time a person spends at a noise source.
- Providing quiet areas where workers can gain relief from hazardous noise sources (e.g., construct a sound proof room where workers' hearing can recover - depending upon their individual noise level and duration of exposure, and time spent in the quiet area).
- Restricting worker presence to a suitable distance away from noisy equipment.

Controlling noise exposure through distance is often an effective, yet simple and inexpensive administrative control. This control may be applicable when workers are present but are not actually working with a noise source or equipment. Increasing the distance between the noise source and the worker, reduces their exposure. In open space, for every doubling of the distance between the source of noise and the worker, the sound level of the noise is decreased by 6.02 dB. No matter what the scale of measurement, you will get about a 6 dB sound level drop for every doubling of distance. You can see how this works by entering values the table in Module 5.6 of the online course.

Hearing protection devices (HPDs), such as earmuffs and plugs, are considered an acceptable but less desirable option to control exposures to noise and are generally used during the time necessary to implement engineering or administrative controls, when such controls are not feasible, or when worker's hearing tests indicate significant hearing damage.

An effective hearing conservation program must be implemented by employers in general industry whenever worker noise exposure is equal to or greater than 85 dBA for an 8-hour exposure or in the construction industry when exposures exceed 90 dBA for an 8-hour exposure. This program strives to prevent initial occupational hearing loss, preserve and protect remaining hearing, and equip workers with the knowledge and hearing protection devices necessary to protect them. Key elements of an effective hearing conservation program include:

- Workplace noise sampling including personal noise monitoring which identifies which employees are at risk from hazardous levels of noise.
- Informing workers at risk from hazardous levels of noise exposure of the results of their noise monitoring.
- Providing affected workers or their authorized representatives with an opportunity to observe any noise measurements conducted.
- Maintaining a worker audiometric testing program (hearing tests) which is a professional evaluation of the health effects of noise upon individual worker's hearing.
- Implementing comprehensive hearing protection follow-up procedures for workers who show a loss of hearing (standard threshold shift) after completing baseline (first) and yearly audiometric testing.
- Proper selection of hearing protection based upon individual fit and manufacturer's quality testing indicating the likely protection that they will provide to a properly trained wearer.
- Evaluate the hearing protector attenuatum and effectiveness for the specific workplace noise.
- Training and information that ensures the workers are aware of the hazard from excessive noise exposures and how to properly use the protective equipment that has been provided.
- Data management of and worker access to records regarding monitoring and noise sampling.

Vibration

Various kinds of tools may cause vibration that could lead to "white fingers" or hand-arm vibration syndrome (HAVS). This is especially dangerous when proper damping techniques are not applied, if machines are not maintained, if tools are not alternated, or if a worker uses a vibrating tool for consecutive hours during a workday. Workers need to be trained on the hazards of working with vibrating tools, and should always allow the tool or machine to do the work.

Hazards and Solutions

Potential Hazards

Both hand-held and stationary tools that transmit vibration through a work piece can cause vibration "white fingers" or hand-arm vibration syndrome (HAVS). White fingers, or Raynaud's Syndrome, is a disease of the hands in which the blood vessels in the fingers collapse due to repeated exposure to vibration. The skin and muscle tissue do not get the oxygen they need and eventually die. HAVS is a more advanced condition, and the entire hand or arm may be affected by exposure to vibration. Early signs of HAVS are infrequent feelings of numbness and/or tingling in the fingers, hands, or arms, or numbness and whiteness in the tip of the finger when exposed to cold. As the disease progresses, a worker experiences more frequent attacks of numbness, tingling, and pain and finds it difficult to use his or her hands. A worker with advanced HAVS may be disabled for a long amount of time.

Possible Solutions

Engineering Controls

Vibration isolators or damping techniques on equipment offer the most effective protection. Isolate machine vibrations from the surface if it is mounted or by use of vibration isolation mounts. Vibrating panels of machine housings and guards may be controlled by use of damping materials applied to the panels. Felts, liquid mastics, and elastomeric damping sheets are effective damping materials. Determining the correct type and quantity of damping material to use for a particular machine is a complicated process and should be left to a knowledgeable person. The frequency emitted by the machine, the noise reduction level desired, and the weight and size of the machine are factors to consider. A good rule of thumb, however, is that the damping layer should be the same thickness as the surfaces being treated.

Work Practices

- Maintain machines in proper working order. Unbalanced rotating parts or unsharpened cutting tools can give off excessive vibration.
- Arrange work tasks so that vibrating and non-vibrating tools can be used alternately.

- Restrict the number of hours a worker uses a vibrating tool during the workday. Allow employees to take 10 to 15 minute breaks from the source of the vibration every hour.
- Train workers about the hazards of working with vibrating tools. Instruction should include: the sources of vibration exposure, early signs and symptoms of hand-arm vibration syndrome, and work practices for minimizing vibration exposure.
- Instruct workers to keep their hands warm and dry, and to not grip a vibrating tool too tightly. Workers should allow the tool or machine to do the work.

Illumination

OSHA Standard: 1915.82, 1926.26, and 1926.56

Potential Hazards:

Inadequate or poor-quality lighting systems can lead to:

- Slips, trips, and falls.
- Electric shocks and burns.
- The inability to exit the space.

Requirements and Example Solutions:

- Temporary lights must have guards or be recessed to prevent accidental contact with the bulb.
- Temporary lights must:
    - Be equipped with heavy duty electric cords.
    - Not be suspended by their electric cords.
    - Have splices equal to the insulation of the cable.
- Cords must be protected from damage.
- Exposed non-current-carrying metal parts of temporary lights must be grounded.

- Temporary lighting must be equipped with overcurrent protection such as fuses or circuit breakers.
- Portable emergency lighting such as flashlights or light sticks must be provided.
- Workers must not enter dark spaces without a suitable portable light.
- Burning torches should not be used to illuminate work areas.

Construction areas, ramps, runways, corridors, offices, shops, and storage areas shall be lighted to not less than the minimum illumination intensities listed below while any work is in progress:

MINIMUM ILLUMINATION INTENSITIES IN FOOT-CANDLES

Foot-Candles	Area of Operation
5.............	General construction area lighting.
3.............	General construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance areas.
5.............	Indoors: warehouses, corridors, hallways, and exitways.
5.............	Tunnels, shafts, and general underground work areas: (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading)
10............	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active store rooms, mess halls, and indoor toilets and workrooms.)
30............	First aid stations, infirmaries, and offices.

Heat

Office Temperature/Humidity

As a general rule, office temperature and humidity are matters of human comfort. OSHA has no regulations specifically addressing temperature and humidity in an office setting. However, Section III, Chapter 2, Subsection V of the OSHA Technical Manual, "Recommendations for the Employer," provides engineering and administrative guidance to prevent or alleviate indoor air quality problems. Air treatment is defined under the engineering recommendations as, "the removal of air contaminants and/or the control of room temperature and humidity." OSHA recommends temperature control in the range of 68-76 degrees Fahrenheit and humidity control in the range of 20%-60%.

Non-Office Work Environments

Operations involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities have a high potential for inducing heat stress in employees engaged in such operations. Such places include:

- iron and steel foundries
- non-ferrous foundries
- brick-firing and ceramic plants
- glass products facilities
- rubber products factories
- electrical utilities (particularly boiler rooms)
- bakeries, confectioneries and commercial kitchens
- laundries
- food canneries
- chemical plants
- mining sites, smelters and steam tunnels

Outdoor operations conducted in hot weather, such as construction, refining, asbestos removal, and hazardous waste site activities, especially those that require workers to wear semipermeable or impermeable protective clothing, are also likely to cause heat stress among exposed workers.

Engineering Controls

Ventilation, air cooling, fans, shielding, and insulation are the five major types of engineering controls used to reduce heat stress in hot work environments. Heat reduction can also be achieved by using power assists and tools that reduce the physical demands placed on a worker.

However, for this approach to be successful, the metabolic effort required for the worker to use or operate these devices must be less than the effort required without them. Another method is to reduce the effort necessary to operate power assists. The worker should be allowed to take frequent rest breaks in a cooler environment.

General Ventilation

This method is used to dilute hot air with cooler air (generally cooler air that is brought in from the outside). This technique clearly works better in cooler climates than in hot ones. A permanently installed ventilation system usually handles large areas or entire buildings. Portable or local exhaust systems may be more effective or practical in smaller areas.

Air treatment/air cooling

This method differs from ventilation because it reduces the temperature of the air by removing heat (and sometimes humidity) from the air.

Air conditioning

This is a method of air cooling, but it is expensive to install and operate. An alternative to air conditioning is the use of chillers to circulate cool water through heat exchangers over which air from the ventilation system is then passed; chillers are more efficient in cooler climates or in dry climates where evaporative cooling can be used.

Local air cooling

This can be effective in reducing air temperature in specific areas. Two methods have been used successfully in industrial settings. One type, cool rooms, can be used to enclose a specific workplace or to offer a recovery area near hot jobs. The second type is a portable blower with built-in air chiller. The main advantage of a blower, aside from portability, is minimal set-up time.

Increasing the air flow

Another way to reduce heat stress is to increase the air flow or convection using fans in the work area (as long as the air temperature is less than the worker's skin temperature). Changes in air speed can help workers stay cooler by increasing both the convective heat exchange (the exchange between the skin surface and the surrounding air) and the rate of evaporation. Because this method does not actually cool the air; any increases in air speed must impact the worker directly to be effective.

Evaporative cooling

If the dry bulb temperature is higher than 35 degrees Celsius (95 degrees Fahrenheit), the hot air passing over the skin can actually make the worker hotter. When the temperature is more than 35°C and the air is dry, evaporative cooling may be improved by air movement, although this improvement will be offset by the convective heat. When the temperature exceeds 35 degrees Celsius and the relative humidity is 100%, air movement will make the worker hotter. Increases in air speed have no effect on the body temperature of workers wearing vapor-barrier clothing.

Heat conduction methods

This method includes insulating the hot surface that generates the heat and changing the surface itself.

Simple engineering controls

Engineering controls, such as shields, can be used to reduce radiant heat. (heat coming from hot surfaces) within the worker's line of sight. Surfaces that exceed 35 degrees Celsius (95 degrees Fahrenheit) are sources of infrared radiation that can add to the worker's heat load. Flat black surfaces absorb heat more than smooth, polished ones. Employers should have cooler surfaces surrounding the worker to help assist in cooling because the worker's body radiates heat toward them.

Heating Pipes

With some sources of radiation, such as heating pipes, it is possible to use both insulation and surface modifications to achieve a substantial reduction in radiant heat. Instead of reducing radiation from the source, shielding can be used to interrupt the path between the source and the worker. Polished surfaces make the best barriers, although special glass or metal mesh surfaces can be used if visibility is a problem.

Shields

Shields should be located so that they do not interfere with air flow, unless they are also being used to reduce convective heating. The reflective surface of the shield should be kept clean to maintain its effectiveness.

Administrative Controls and Work Practices

Training is the key to good work practices. Unless all employees understand the reasons for using new, or changing old, work practices, the chances of such a program succeeding are greatly reduced.

NIOSH (1986) states a good heat stress training program should include at least the following components:

- knowledge of the hazards of heat stress
- recognition of predisposing factors, danger signs, and symptoms
- awareness of first-aid procedures for, and the potential health effects of, heat stroke
- employee responsibilities in avoiding heat stress;
- dangers of using drugs, including therapeutic ones, and alcohol in hot work environments
- use of protective clothing and equipment
- purpose and coverage of environmental and medical surveillance programs and the advantages of worker participation in such programs

Hot jobs should be scheduled for the cooler part of the day, and routine maintenance and repair work in hot areas should be scheduled for the cooler seasons of the year.

Other Administrative Controls

The following administrative controls can be used to reduce heat stress:

- Reduce the physical demands of work, e.g., excessive lifting or digging with heavy objects.
- Provide recovery areas, e.g., air-conditioned enclosures and rooms.
- Use shifts, e.g., early morning, cool part of the day, or night work.
- Use intermittent rest periods with water breaks.
- Use relief workers.
- Use worker pacing.
- Assign extra workers and limit worker occupancy, or the number of workers present, especially in confined or enclosed spaces.

Module 5 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **The physical hazards employees face in the workplace include ________.**

    a. excessive levels of ionizing and nonionizing electromagnetic radiation, and noise
    b. vibration, illumination, and temperature
    c. bloodborne pathogens
    d. both a and b

2. **Employees work with non-ionizing radiation for which of these common tasks?**

    a. Telecommunications and heating food
    b. Infrared lamps to keep food warm in restaurants
    c. Broadcasting
    d. All the above

3. **Jack is leaving work and he hears ringing in his ears. This is a warning sign that his workplace may be too _______.**

    a. stressful
    b. noisy
    c. quiet
    d. all the above

4. **The National Institute for Occupational Safety and Health (NIOSH) has recommended that all worker exposures to noise should be controlled below a level equivalent to _______ for eight hours to minimize occupational noise induced hearing loss.**

    a. 60 dBA
    b. 75 dBA
    c. 85 dBA
    d. 100 dBA

5. **Placing a barrier between a noise source and an employee is an example of an _______.**

    a. physical control
    b. hearing protection device
    c. administrative control
    d. engineering control

6. **Peter frequently works with jack hammers; he has recently been feeling numbness and tingling in his fingers, hands, and arms. These may be early signs of _______.**

    a. digital neuropathy
    b. legionnaires' Disease
    c. hand-Arm Vibration Syndrome (HAVS)
    d. hantavirus

7. **Inadequate or poor-quality lighting systems can lead to ________.**

    a. slips, trips, and falls
    b. electric shocks and burns
    c. the inability to exit the space
    d. all the above

8. **_______ are the major types of engineering controls used to reduce heat stress in hot work environments.**

    a. Ventilation, air cooling and fans
    b. Use of protective clothing and equipment and reducing the physical demands of the work
    c. Shielding and insulation
    d. Both a and c

Module 6: Ergonomic Hazards

Ergonomics (er'gõ nom'iks)

Webster's New World Dictionary (College Edition) defines ergonomics as "the study of the problems of people in adjusting to their environment; especially the science that seeks to adapt work or working conditions to suit the individual worker. In other words, ergonomics is the study of work and the relationship of work to the physical and cognitive capabilities of people for the purpose of fitting the job (tools, tasks, and environment) to the employee, instead of forcing the worker to fit the job.

Ergonomics studies the various risk factors brought to a job. Listed below are three areas within which ergonomic risk factors exist.

- Risk factors inherent in the worker
- Risk factors inherent in the task
- Risk factors inherent in the environment

Ergonomic principles are derived from many areas, including:

- Biomechanics
- Physiology

- Anthropometry
- Industrial engineering
- Safety

The IH and Ergonomics

The industrial hygienist may evaluate working conditions from an ergonomics standpoint which requires looking at the total physiological and psychological demands of the job on the worker.

The science of ergonomics studies and evaluates a full range of tasks including, but not limited to, lifting, holding, pushing, walking, and reaching. Many ergonomic problems result from:

- technological changes such as increased assembly line speeds
- adding specialized tasks
- increased repetition
- poorly designed job tasks
- improperly designed tools, equipment and work area.

Any of those conditions can cause ergonomic hazards such as excessive vibration and noise, eye strain, repetitive motion, and heavy lifting problems.

Repetitive motions or repeated shocks over prolonged periods of time as in jobs involving sorting, assembling, and data entry can often cause irritation and inflammation of the tendon sheath of the hands and arms, a condition known as carpal tunnel syndrome.

Controlling Ergonomic Hazards

Ergonomic hazards are avoided primarily by the effective design of a job or jobsite and better designed tools or equipment that meet workers' needs in terms of physical environment and job tasks. Through thorough worksite job hazard analysis (JHA), employers can use the same Hierarchy of Controls strategies discussed in Module 1 to correct or control ergonomic hazards. Examples include:

- eliminating the hazard or substituting it with something less hazardous (e.g., using hand-trucks to eliminate the need to lift carry heavy boxes, or replacing heavy bags with lighter bags);
- using appropriate engineering controls (e.g., designing or re-designing work stations, lighting, tools, and equipment);
- employing proper administrative controls (e.g., shifting workers among several different tasks, reducing production demand, and increasing rest breaks);
- using correct work practices (e.g., proper lifting techniques); and
- if necessary, providing personal protective equipment such as knee guards while laying carpet or wood floors. (Note: Backbelts should not be used for prolonged periods as they may weaken back muscles.)

Overall, industrial hygienists point out that the benefits of a well-designed, ergonomic work environment can include increased efficiency, fewer accidents, lower operating costs. and more effective use of personnel.

Ergonomic Guidelines

A major component of ergonomics is the development of industry-specific and task-specific guidelines to reduce and prevent workplace musculoskeletal disorders (MSDs). These voluntary guidelines are tools to assist employers in recognizing and controlling ergonomics-related risk factors. Employers in other industries for which guidelines have not been developed may find useful information in these guidelines for implementing their own ergonomic programs.

Current Ergonomics Guidelines

- Guidelines for Shipyards: Ergonomics for the Prevention of Musculoskeletal Disorders. OSHA 3341-03N, (2008). Also available as a 2 MB PDF, 52 pages.

OSHA issued the ergonomic guidelines for the shipyards industry on February 28, 2008.

- Guidelines for Poultry Processing: Ergonomics for the Prevention of Musculoskeletal Disorders. OSHA 3213-09N, (2004). Also available as a 580 KB PDF, 28 pages.

OSHA issued the ergonomic guidelines for the poultry processing industry on September 2, 2004.

- Guidelines for Retail Grocery Stores: Ergonomics for the Prevention of Musculoskeletal Disorders. OSHA 3192-05N, (2004). Also available as a 921 KB PDF, 29 pages.

OSHA issued the ergonomic guidelines for the retail grocery stores industry on May 28, 2004.

- Guidelines for Nursing Homes: Ergonomics for the Prevention of Musculoskeletal Disorders. OSHA 3182, (Revised 2009). Also available as a 2 MB PDF, 44 pages.

OSHA issued the ergonomic guidelines for the nursing home industry on March 13, 2003. The document was updated on September 12, 2005.

Previously Completed Ergonomic Guidelines

- Ergonomics Program Management Guidelines for Meatpacking Plants. OSHA, (1993).

Ergonomic Injuries

Classifications of Ergonomic Injuries

There are two classifications of ergonomic injuries, and they are:

- Cumulative Trauma Disorders (CTD's) - exposure driven
- Strains/Sprains - instantaneous (event driven)

Characteristics of Cumulative Trauma Disorders (CTD's) are:

- Injury to soft tissue caused by prolonged exposure to multiple ergonomic risk factors
- Typically develop in small body segments (i.e. fingers, wrists, elbows, and neck)

Examples of CTD's

Tendon disorders:

- Inflammation of tendon and/or tendon sheathing caused by repeated rubbing against ligaments, bone, etc.
- Lateral epicondylitis (tennis elbow)

Nerve disorders:

- Compression of nerves from repeated or sustained exposure to sharp edges, bones, ligaments, and/or tendons
- Carpal tunnel syndrome

Neurovascular disorders:

- Compression of blood vessels and/or nerves from repeated exposure to vibration or cold temperatures
- Raynaud's phenomenon (white finger syndrome)

Characteristics of Strains & Sprains

- Injury to connective tissue caused by single forceful event: lifting heavy objects in awkward position
- Common to large body segments (i.e. back, legs, and shoulders)
- Risk of injury increases with the presence of multiple risk factors

Early Reporting of Ergonomic Issues

Office Ergonomics - SAIF

It is critical for employees to understand the importance of reporting ergonomic issues sooner rather than later to help prevent serious injuries from occurring.

Proactive Reporting

- Report suspected ergonomics risk factors to your supervisor and safety committee representative

Early Reporting Process

- Report pain or discomfort associated with work to your supervisor and Occupational Health Services

Benefits to Early Reporting

- Leads to early care and quicker healing, preventing chronic problems
- Leads to quicker identification of the root cause of the injury
- Will initiate an ergonomics evaluation by trained personnel

Stretching Basics

Stretching helps reduce the likelihood of ergonomic injury from occurring in the workplace.

The Benefits of Stretching:

- Increases flexibility/elasticity of muscles
- Increases circulation to warm the muscles, improving mental alertness, reducing fatigue
- Decreases muscle tension and stress

When to Stretch:

- Prior to starting your day
- During short breaks (at least once per hour)
- After breaks or lunch to prevent fatigue
- If tension or stress is apparent
- After a lengthy task duration or an extended awkward posture

Proper stretching techniques:

- Relax and breathe normally. Do not hold your breath.

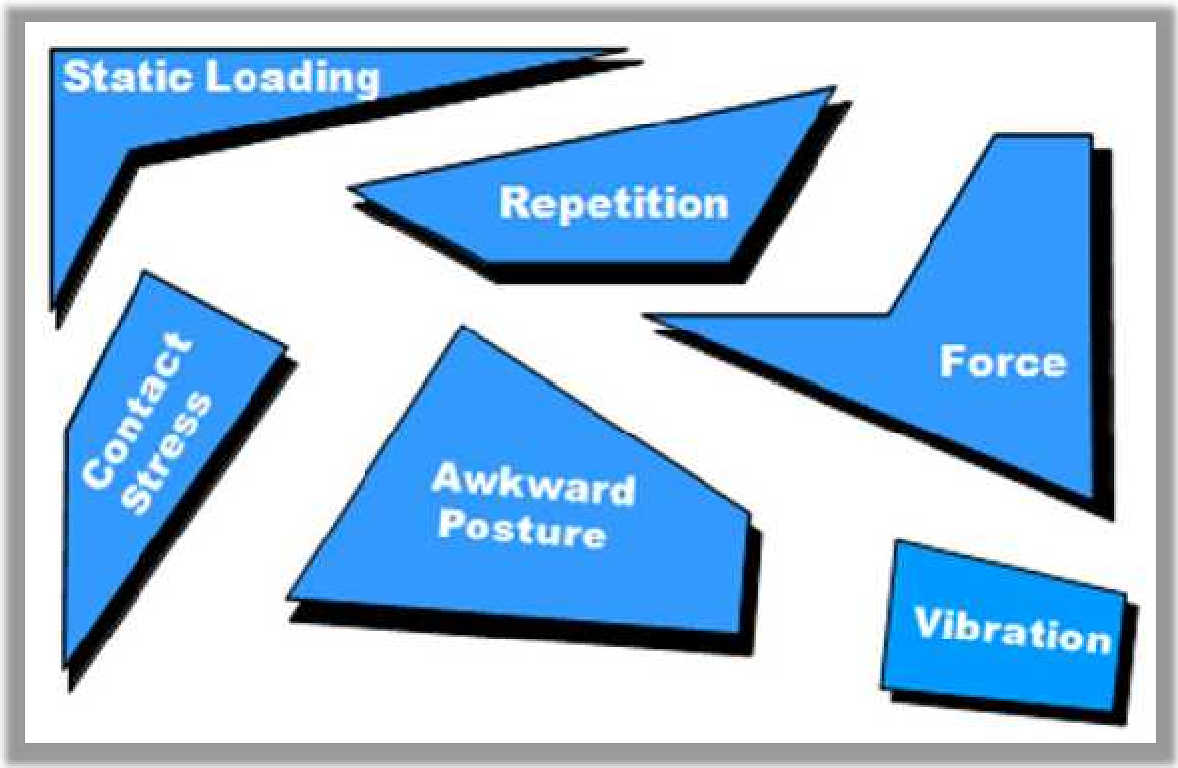
- Hold each stretch for a count of 15, or as long as comfort is maintained.
- Use gentle, controlled motions. Do not bounce!

- Keep the knees slightly bent for better balance.
- Stretch until a mild tension is felt, then relax.
- Stretch by how you feel and not by how far you can go.

Ergonomic Risk Factors

Risk of injury increases with:

- Prolonged exposure to any of the ergonomic risk factors shown below
- Presence of multiple risk factors within a single job task


Static Loading
Repetition
Force
Contact Stress
Awkward Posture
Vibration

Module 6 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **The science of ergonomics studies and evaluates a full range of tasks including, but not limited to, ______.**

   a. lifting, holding, and pushing
   b. the creation and use of Material Safety Data Sheets
   c. walking, and reaching
   d. both a and c

2. **Overall, the benefits of a well-designed, ergonomic work environment can include increased efficiency, fewer accidents, lower operating costs. and more effective use of personnel.**

   a. True
   b. False

3. **Ergonomics is _______.**

   a. the study of chemical and biological hazards in the workplace
   b. the study of work and the relationship of work to the physical and cognitive capabilities of people
   c. fitting the job (tools, tasks, and environment) to the employee, instead of forcing the worker to fit the job
   d. both b and c

4. **There are two classifications of ergonomic injuries, and they are _______.**

   a. cumulative Trauma Disorders (CTD's)
   b. strains/sprains – instantaneous
   c. radiant heat exposure
   d. both a and b

5. **A benefit of reporting ergonomic issues sooner rather than later is _______.**

    a. it leads to slower identification of the root cause of the injury
    b. it will delay an ergonomics evaluation by trained personnel
    c. it will lead to early care and quicker healing, preventing chronic problems
    d. both a and b

6. **Tonya is an employee at ABC Inc. She often sits for long periods of time and her job is stressful. If she were to stretch when appropriate some of the benefits would be _______.**

    a. an increase in flexibility/elasticity of muscles
    b. an increase in circulation to warm the muscles, improving mental alertness and reducing fatigue
    c. a decrease in muscle tension and stress
    d. all the above

7. **When should you stretch?**

    a. Prior to starting your day and during short breaks (at least once per hour)
    b. After breaks or lunch to prevent fatigue and if tension or stress is apparent
    c. After a lengthy task duration or an extended awkward posture
    d. All the above

8. **Which of the below are ergonomic risk factors?**

    a. Dynamic loading
    b. Static loading
    c. Good posture
    d. Non-contact stress