Protecting Yourself from Respiratory Hazards in Agriculture

K-STATE
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Contents

Lesson 1.
Respiratory Hazards in Agriculture

Farmers often enjoy good health due to an active lifestyle, a balanced diet, and healthful habits. Still, farm work can be hazardous. Consider, for instance, that farming sometimes exposes workers to harmful contaminants in the air. Here are some examples:

Agricultural dust and mold may cloud the air while handling grain, caring for livestock, tilling, and harvesting. Breathing high concentrations of dust and mold can cause temporary, flu-like symptoms. In addition, long-term conditions such as asthma and chronic obstructive pulmonary disease (COPD) can result. Exposure is limited through ventilation, moisture control, and respirators.

Gases from livestock waste handling systems may irritate the respiratory tract. In pits and unventilated spaces, high levels of these gases can cause sudden death. Limit exposure by increasing barn ventilation or relocating workers and animals when waste is agitated or pumped. Stay out of waste storage pits unless you follow special confined-space procedures.

Toxic gases and low oxygen levels may occur in farm storage tanks, wells, silage structures, and commodity storage areas. Confined-space procedures may be required in some of these locations.

Figure 1.1. Livestock bedding can be a source of dust, mold, and bacteria in barns.

Figure 1.3. Farm storage areas, including bins and silos, may contain toxic gases or low oxygen levels.

Figure 1.2. Livestock waste produces hydrogen sulfide and other gases.

Figure 1.4. Workers can be exposed to pesticides during and after applications on the farm. (Credit: Agricultural Research Service)

Pesticides during restricted entry intervals create residues on surfaces and emit vapors into the air. Do not enter growing areas when application signs are posted unless you are trained and properly equipped as a pesticide handler.

Anhydrous ammonia can be released unexpectedly while filling and adjusting equipment. Avoid injuries by wearing protective gear and following the equipment manufacturer's instructions.

Exhausts from internal combustion engines and fuel-burning appliances release carbon monoxide and other harmful substances. Make sure equipment and appliances are properly vented.

Welding fumes and gases can cause temporary flu-like symptoms. More serious long-term effects are also possible. Select and prepare materials carefully, use good ventilation, and wear respirators when needed.

Figure 1.7. Workers are exposed to fumes and gases during hot work such as torch cutting and welding.

Figure 1.5. Accidental exposure to pressurized anhydrous ammonia can damage the respiratory system, eyes, and skin.

Figure 1.8. Cleaning products may be incompatible with one another. Mix them only if labels allow.

Figure 1.6. Ventilation is required when fuel-fired appliances and engines are used indoors.

Figure 1.9. Some solvents and maintenance chemicals require extra ventilation and protective equipment.

Cleaning products can produce harmful vapors, especially when incompatible products are mixed. Always follow label instructions and mix products only when the labels allow.

Everyday maintenance activities expose workers to fuels, solvents, water chlorinators, and lead-based paint. Use good ventilation, observe all label instructions, and do not disturb lead-based paint.

The following pages examine these hazards more closely and discuss how to get the farm work done while maintaining good respiratory health.

Discussion

1. Which respiratory hazard from this lesson do you feel is the most important in your workplace? Include the following:
   a. Describe the hazard and tell how you might encounter it in your work.
   b. Discuss any precautions you can think of.
   c. How confident are you that you can take these precautions?
   d. What questions or concerns do you have about this hazard?

Lesson 2.
Dust from Grain, Hay, Compost, and Livestock

Dust is common on farms. It comes from animals, plants, soil, vehicle exhaust, and other sources. Here are some key facts:

- Agricultural dust builds up in places like barns, feedlots, hay storage, grain bins, and compost piles.
- Farm dust often contains mold, bacteria, and dust mites.
- Exposure to farm dust can cause allergic or toxic reactions. Some effects are mild, like a runny nose and itchy eyes. Other reactions are severe and require medical attention.

This section discusses severe reactions to dust and methods for controlling exposure.

Severe Reactions to Dust

Organic dust toxic syndrome (ODTS)

Description: ODTS is a common, flu-like illness that usually lasts a few days. It occurs after a brief

Figure 2.1. The dust mite, Tyrophagus putrescentiae, is common in stored grain and animal feed. This mite is also known as the mold mite, ham mite, cheese mite, and copra mite. It causes allergic reactions in some people. (Credit: Agricultural Research Service)

Figure 2.3. Swine barns can be dusty with animal dander, feed, and trampled manure. (Credit: Agricultural Research Service)

Figure 2.2. Sources of dust in poultry barns include feathers, dander, bedding, manure, and feed. (Credit: Agricultural Research Service)

Figure 2.4. Dust from feed, bedding, manure, and other sources is present in cattle barns.

exposure to dusty air from decomposing plant materials. It can be triggered by shoveling deteriorating grain, hay, silage, animal bedding, or compost in an enclosed area. It is quite common. At least one-quarter of all farmers have experienced it at least once. It is believed to be caused by toxins from bacteria or fungi. It is not an allergic reaction.

Signs and symptoms: Fever, chills, headache, muscle ache, cough, chest discomfort, and extreme fatigue are likely. Symptoms usually begin within a few hours of exposure.

Treatment and outcomes: The illness usually goes away after a few days. Severe or prolonged cases may require a doctor's care.

Other names: This illness is also known as grain fever, silo unloader's syndrome, mill fever, inhalation fever, pulmonary mycotoxicosis, toxic pneumonitis, toxic alveolitis, or precipitin-negative farmer's lung disease.

Asthma

Description: Asthma is a long-term condition that causes inflammation and narrowing of the airways. During an asthma attack, air passages in the lungs become irritated and swollen, making it hard to breathe. Asthma can have many causes, including agricultural dust.

Symptoms: Wheezing, shortness of breath, chest congestion, and cough are typical.

Prevention, treatment, and outcomes: Asthma attacks may be prevented by avoiding allergens and other triggers. When attacks occur, they can usually be treated with medicines, but severe attacks can be life-threatening. Chronic asthma may last a lifetime. Talk with your doctor and follow medical advice.

Hypersensitivity pneumonitis (HP)

Description: HP is a rare condition that occurs when the immune system overreacts to allergens. There are two different forms of HP: Acute and chronic. Acute HP is triggered by intense exposure to high concentrations of dust or allergens. Recovery from acute HP usually happens within a few days or weeks. A smaller percentage of people develop chronic HP, which can cause long-term poor health.

Signs and symptoms: Acute HP is a brief, flu-like illness that causes cough, shortness of breath, fever, chills, headache, and muscle aches (much like ODTS). Chronic HP is long-lasting and may cause permanent lung damage.

Treatment and outcomes: HP is managed by avoiding allergens and taking medication to help with symptoms. If caught and treated early, complete recovery is possible. It is important to avoid allergens if you are diagnosed with HP; otherwise, severe long-term effects may occur.

Other names: This illness is sometimes called farmer's lung, pigeon fancier's lung, humidifier lung, bagassosis, and extrinsic allergic alveolitis.

Figure 2.5. Dust from stored grain may contain a variety of allergens.

Figure 2.6. Compost-turning activities may release dust-containing plant debris, mold, and bacteria.

Chronic obstructive pulmonary disease (COPD)

Description: COPD is a long-lasting disease that limits airflow in the lungs. Smoking is the most common cause, but overexposure to dust and toxic gases increases the risk. COPD usually gets worse over time. There is no cure, but COPD can be managed. The two most common types of COPD are chronic bronchitis and emphysema. Chronic bronchitis is an inflammation of the bronchial airways. Emphysema involves damage to the alveoli, which are tiny air sacs in the lungs.

Signs and symptoms: People with COPD may experience a cough that does not go away, excessive mucus, shortness of breath, wheezing, fatigue, and frequent lung infections. Symptoms may worsen in extremely hot or cold weather.

Figure 2.7. Wear a dust mask to avoid respiratory symptoms when changing old animal bedding. (Credit: Agricultural Research Service)

Management: Medications and other treatments may help with the symptoms. It is also important to avoid smoke, dust, allergens, and other triggers. COPD cannot be cured, but it can be managed to improve the quality of life.

Case Reports

Here is a sample of actual cases that illustrate how workers are exposed to agricultural dust.

Workers sickened by dust from spoiled grain: Two workers were unloading old grain from a silo. The grain was dusty, and they had to stop often because of burning eyes and coughing. A few hours after finishing for the day, both men became ill. They were diagnosed with organic dust toxic syndrome (ODTS). One worker's case was reported in detail and is summarized here: Within a few hours after leaving work, he experienced shortness of breath, muscle pains, sweating, a fever of 102 degrees Fahrenheit, and constant coughing. The next day, he went to the hospital. Listening to his chest, doctors could hear signs of fluid in his lungs. By the next day, his fever was gone, and he felt well. He was kept at the hospital for a few more days but recovered with no permanent effects. *This case is typical of ODTS because it occurred shortly after massive exposure to agricultural dust. Symptoms were flu-like, the lungs were inflamed, and the worker recovered quickly.* Source: Raymenants, E., Demedts, M., & Nemery, B. (1990). Bronchoalveolar lavage findings in a patient with the organic dust toxic syndrome. *Thorax, 45,* 713-714.

Farmer suffers lung damage from years of handling moldy hay: A 37-year-old farmer became ill and visited a medical center after handling moldy hay. Signs and symptoms included shortness of breath, a dry cough, wheezing, fever, and chills. He told doctors that for the past two years, he had often experienced these symptoms when working with moldy hay. Doctors confirmed that his chest was not fully expanding, and they suspected fluid in his lungs. A biopsy of lung tissue showed signs of long-term inflammation and scarring. His condition was likely caused by years of feeding moldy hay to livestock. Source: Ghose, T., Landrigar, P., Killeen, R., & Dill, J. (1974). Immunopathological studies of patients with

farmer's lung. *Clinical & Experimental Allergy*, *4*(2), 119-129.

Dust from moldy silage causes severe, but temporary, illness: A healthy 40-year-old farmer felt a burning sensation in his eyes, throat, and chest after working with moldy silage for about an hour. By evening, he was experiencing chills, fever, and a dry cough. The next morning, his cough was much worse, and he was feeling weak. He went to the hospital, where doctors found inflammation and fluid in his lungs. He was diagnosed with pulmonary mycotoxicosis (another name for ODTS). He responded well and recovered fully after a few weeks. Source: Perry, L. P., Iwata, M., Tazelaar, H. D., Colby, T. V., & Yousem, S. A. (1998). Pulmonary mycotoxicosis: a clinicopathologic study of three cases. *Modern Pathology, 11*(5), 432-436.

Figure 2.8. Consider the benefits of sand bedding, which may harbor fewer allergens than straw or other organic materials.

Dusty work causes a prolonged case of ODTS: A 52-year-old farmer developed a fever and worsening shortness of breath after cleaning a chicken coop and baling hay. He went to the hospital and was found to have fluid in his lungs. Doctors treated him with antibiotics, but he continued to get worse. He was transferred to a different facility a week later, where he required mechanical ventilation and further antibiotics. He slowly improved and fully recovered after rehabilitation. Source: Perry, L. P., Iwata, M., Tazelaar, H. D., Colby, T. V., & Yousem, S. A. (1998). Pulmonary mycotoxicosis: a clinicopathologic study of three cases. *Modern Pathology, 11*(5), 432-436.

Protect Yourself and Others

The following methods have proven effective for limiting exposure to dust.

Livestock bedding: Use sand instead of hay and other organic materials.

Grain storage: Maintain bins properly. Prevent spoilage by ventilating, cooling, and drying grain. Remove fines to increase airflow. Consider storage additives to preserve grain quality.

Hay and straw management: Use an appropriate conditioning mower, and make sure hay is adequately dried before baling. Store off the ground, indoors, or under cover. When stacking, space the bales to improve ventilation. When shredding, moisten hay bales and wear a respirator.

Figure 2.9. Stay out of grain bins and use mechanical unloading conveyors.

Silage: Use commercial additives to prevent mold growth.

Grain handling: Stay out of bins when possible. Use mechanized grain unloading equipment. For large grain-handling operations, enclose and ventilate conveyors. Filter exhausted conveyor air with cyclones and baghouses.

Feeds and feeding: Add fat, oil, molasses, or other substances to reduce dust in granular feeds. For mechanical feeding, use extension spouts to deliver feed into covered feeders.

Ventilate buildings and equipment cabs: Maintain air filtration systems according to the manufacturer's recommendations.

Animal confinement facilities:

- Wear respirators or dust masks while working in swine and poultry units.
- Install self-cleaning flooring and power wash frequently. Wear dust masks when power washing.
- Clean and maintain fans and heating units regularly.
- Control dust on floors and pen surfaces with a light sprinkling of vegetable oil and water.
- Maintain adequate ventilation based on the design of the facility, type of livestock, season of year, control of temperature, and relative humidity. Design ventilation systems to limit the disturbance of settled dust and minimize the influx of gases from underfloor manure handling spaces.

Figure 2.10. Reduce decomposition by protecting hay and straw from rain and other sources of moisture.

Figure 2.12. Self-cleaning floors help reduce worker exposure to manure.

Figure 2.11. Maintain air filtration systems to keep dust out of equipment cabs.

Figure 2.13. Robotic cleaners help keep barn floors clean.

Asbestos: Seek professional advice before disturbing materials that contain asbestos. Examples of asbestos-containing materials include certain cement pipes, cement shingles, and some types of pipe insulation.

Respirators: Wear respirators (such as an N95 filtering facepiece) when shoveling grain, turning compost, shredding hay, moving animals, feeding, milking, disturbing litter/bedding, disturbing the nests of wild birds or rodents, scraping floors, sweeping, and power washing.

Smoking: Avoid smoking. Seek help to quit.

Job reassignment: Protect workers with preexisting respiratory conditions or dust allergies.

Figure 2.14. Wear a dust mask (filtering facepiece respirator) when power washing barn floors.

Figure 2.15. Maintain adequate ventilation to dilute dust and hazardous gases in barns.

Discussion

1. Consider the facts about dust and severe reactions in the first part of this lesson. Discuss the following:
   a. During what tasks are you most exposed to agricultural dust at your job?
   b. Describe any precautions you have already been following to reduce your exposure to dust.
2. Consider the case report "Workers Sickened by Dust from Spoiled Grain." Explain any two of the safety recommendations in the "Protect Yourself and Others" section that could have prevented the workers' illness.
3. Consider the case report "Farmer Suffers Lung Damage from Moldy Hay." Explain two different safety recommendations in the "Protect Yourself and Others" section that could have prevented the illness. Use recommendations that are different from those you reported in the previous question.
4. Consider the case report "Dust from Moldy Silage Causes Severe, but Temporary, Illness." Explain two additional safety recommendations in the "Protect Yourself and Others" section that could have prevented the illness. Use recommendations that are different from those you reported in the previous questions.
5. Discuss any other precautions you would like to take from the "Protect Yourself and Others" section of this lesson.
6. What barriers might keep you from taking the precautions?
7. How might you overcome those barriers?

Quiz Yourself

1. Shoveling deteriorating grain, hay, silage, animal bedding, or compost in an enclosed area _____ fever, chills, aches, and cough that go away after a few days.
   a. may cause
   b. does not cause
2. Severe, long-lasting lung disease is more common in people who _____.
   a. work in dusty environments and smoke
   b. work in dusty environments but do not smoke
3. Keep stored grain from spoiling by keeping it _____.
   a. wet
   b. dry
4. Keep hay from becoming moldy by storing it _____.
   a. under cover
   b. outdoors
5. Which will protect you from dust when moving grain?
   a. stay out of the bin and use a conveyor
   b. get inside the bin and use a shovel
6. Adding oil or molasses will make animal feed _____.
   a. more dusty
   b. less dusty
7. Protect your lungs by wearing a _____ in swine and poultry barns.
   a. beard
   b. dust mask

Lesson 3.
Manure Gases from Waste Handling Systems

Many livestock barns have built-in systems to remove animal waste. Here are some key facts:

- Waste flows to collection areas through gutters or openings in the floor. There are many variations in design, such as:
  - Waste may flow to underground pits. These pits may be located directly under the floor, or they may be some distance away. Some pits are deep, while others are shallow.
  - Waste may flow through pipes to above-ground tanks. Some tanks are open, while others are covered.
  - Manure and urine may be piped to holding ponds or lagoons.
  - Waste may be pumped into portable tanks to be spread on fields.
  - On poultry farms, waste may be handled as a solid or conveyed as a liquid slurry.
- Deadly gases can accumulate in waste pits. You can die if you enter a pit without taking the necessary precautions.
- Under certain conditions, gases from waste storage areas may enter barns or the open air.

Figure 3.1. Animal waste drains through floor slats to storage pits or gutters below.

Figure 3.3. Animal waste is flushed toward collection areas during the cleaning of concrete floors.

Figure 3.2. Mesh flooring allows manure and urine to flow to collection areas beneath the floor. (Credit: Agricultural Research Service)

Figure 3.4. This barn floor is under construction. Note the deep manure storage pits directly beneath the slatted floors.

  - Low concentrations of gases may be present in a livestock barn at any time manure and urine are present under slatted floors.
  - Deadly concentrations of gases are most likely to enter barns and open areas when waste is being agitated, pumped, flushed with running water, or drained.
  - Well-designed ventilation systems can significantly reduce gas concentrations in barns.
- Common waste gases include hydrogen sulfide, ammonia, methane, and carbon dioxide. These gases are produced naturally as microorganisms break down manure, urine, and sludge.
  - Hydrogen sulfide, often called sewer gas, is invisible, poisonous, and flammable. At low concentrations, it may smell like rotten eggs. You quickly lose sensitivity to the odor, so it may have no smell at all. Continued exposure to low concentrations may lead to the development of asthma. Higher concentrations of hydrogen sulfide can cause eye irritation, coughing, shortness of breath, headache, dizziness, nausea, vomiting, confusion, unconsciousness, coma, and sudden death.
  - Ammonia is a corrosive gas. Even at low concentrations, it may irritate the eyes, nose, throat, and lungs. Higher concentrations may cause death or permanent damage to the respiratory system.
  - Other waste gases may be explosive or displace oxygen in the air. Many of these, such as methane and carbon dioxide, are invisible and have no odor or other warning properties.

Figure 3.5. Open-air, above-ground livestock waste storage tanks.

Figure 3.7. Open-air animal waste lagoon with vegetative mats to absorb nutrients. (Credit: Agricultural Research Service)

Figure 3.6. Covered above-ground manure storage tank.

Figure 3.8. A tanker truck spreads liquid animal waste onto a field.

- Deaths from exposure to waste gases have been documented at swine, dairy, beef, and poultry farms. Cases may occur any time of year.
- **Nearly all deaths can be prevented by staying out of waste storage structures and by temporarily relocating people and animals away from areas where waste is being agitated or pumped.**

Case Reports

Here is a sample of cases that illustrate how workers have been injured when precautions were not observed.

Hazards of entering manure storage and handling structures

Two brothers die in manure pit. A 31-year-old dairy farmer entered a 4.5-foot-deep, 25-foot-square manure pit to clear a clogged pipe. He was overcome by waste gases and collapsed inside. His 33-year-old brother tried to rescue him but also collapsed in the pit. A family member found them several hours later and summoned help. The fire department recovered the bodies, and they were pronounced dead at the scene. The coroner listed the cause of death as methane asphyxiation. Source: National Institute for Occupational Safety and Health (1990). *NIOSH alert: Request for assistance in preventing deaths of farm workers in manure pits.* DHHS (NIOSH) Publication No. 90–103. U.S. Government Printing Office, Washington, DC.

Farm hand overcome by gases in manure tower. A farm hand entered a 12-foot-tall, 5-foot-diameter concrete pumping tower in a manure pond to unclog an inlet. Manure water flowed in as soon as he unclogged the opening. While climbing the ladder to leave, he was overcome by waste gases and fell to the bottom of the tower. He recovered, but the inlet clogged again, so he cleared the opening once more. He tried to climb up the ladder but was overcome and fell with his head in the incoming flow of manure water. The farm owner tried to rescue him but also lost consciousness. The owner's family members recovered both victims. The farm hand had drowned, while the owner was revived and taken to the hospital. Source: *OSHA Inspection 126760446*.

Rescuer dies trying to help collapsed dairy worker in manure tanker truck. A dairy worker was overcome by waste gases and collapsed while cleaning inside a manure tanker truck. A coworker tried to rescue him but also collapsed. The rescuer died of asphyxiation, but the other worker survived. Source: *OSHA Inspection 315004135*.

Hazards of working in barns during manure disturbance

Worker overcome in hallway of swine barn during manure pit pump-out. A worker was tending hogs in a swine barn while manure was being pumped from a pit under one of the confinement rooms. As the manure was disturbed, it released hydrogen sulfide into the building. The worker was overcome and passed out in a hallway between two confinement rooms. The fire department responded, but the worker could not be saved. The coroner reported the cause of death as respiratory failure due to hydrogen sulfide poisoning. Source: *OSHA Inspection 314197732*.

Worker in calf barn overcome by gases from agitation of manure tank. A 10,000-gallon underground manure storage tank was being agitated at a calf barn. At the same time, a 16-year-old farm worker was cleaning manure from gutters in the barn using a high-pressure hot-water spray. Soon, he started coughing, then vomited and collapsed. Other workers tried to help but had to stop when they also began losing consciousness. The 16-year-old died. An autopsy indicated death was caused by aspiration of vomit caused by toxic gas inhalation. Source: Morse, D. L., Woodbury, M. A., Rentmeester, K., & Farmer, D. (1981). Death caused by fermenting manure. *Journal of the American Medical Association, 245*, 63–64.

Hazards near outdoor open-air manure storage structures

Fatalities during agitation of open-air manure storage structures. Researchers at Penn State reported several recent incidents in which dairy farmers were killed by gases during agitation of open-air, uncovered manure storage structures. During agitation, authorities recommend keeping workers at least 20 feet away and out of any nearby

low-lying areas. Source: Penn State University Agricultural Sciences. (2023). *Extension experts release guidelines to increase safety of manure-storage.*

Hazards to children

Child dies in manure pit at grandparents' farm. A 4-year-old boy went missing while helping his grandfather with chores on the farm. After a 15-minute search, he was found face down in a manure pit under the slatted floors of a swine building. The boy had fallen where a section of slats had been removed. Resuscitation was unsuccessful. No autopsy was performed, but the medical examiner listed the cause of death as "... a combination probably of drowning and suffocation from the toxic fumes from the manure pit." Source: Donham, K. J., Knapp, L. W., Monson, R., & Gustafson, K. (1982). Acute toxic exposure to gases from liquid manure. *Journal of Occupational and Environmental Medicine, 24*(2), 142-145.

Hazards to livestock

Poultry killed from gas after agitation of underfloor manure pit. The morning after manure had been stirred under the floor of a poultry house, 76 birds were found dead, and 46 others were near death from a flock of 4,000 layers. The affected birds were all located near manholes leading to a manure pit under the floor. Researchers recreated the event a few weeks later by stirring manure and measuring toxic gas levels. They found high levels of hydrogen sulfide at cage locations near the manholes. Similar events have been reported, with losses of swine and cattle in barns during stirring and pumping underfloor manure pits. Source: Blaxland, J. D., Shemtob, J., Francis, G. H., & Jones, G. E. 1978. Mortality in a battery laying house attributed to the presence of noxious gases from slurry. *Veterinary Record, 103*, 241–242.

Protect Yourself and Others

Location: Locate new manure pits as far away from buildings as feasible.

Limit access: Keep people and livestock away from waste storage pits, tanks, ponds, and lagoons:

- For open-air storage structures, use fences with locked gates and warning signs.
- For pits and tanks, use warning signs and locked covers. Covers can be made of grates to provide ventilation.
- Design all barriers to keep out children, adults, and livestock.

Emergency response: Leave barns immediately and call 911 if someone shows signs of manure gas poisoning, such as burning eyes, coughing, shortness of breath, headache, nausea, vomiting, staggering, erratic behavior, or unconsciousness. Do not attempt rescue without proper confined space entry procedures and equipment.

Figure 3.9. Underground manure pit being pumped. Toxic gas concentrations can increase in occupied areas of barns when waste is flushed, agitated, or pumped.

Ventilation: Maintain ventilation systems to keep them working properly.

- Ventilation systems must be balanced to ensure proper airflow and to prevent waste gases from entering the working areas of barns.
- Consult a ventilation expert if airflow seems inadequate or if you are designing a new facility. Your county extension agent or livestock association can refer you to qualified designers and installers. Here are some general considerations:
  - Waste storage pits can be designed so mechanical ventilation directs gases outdoors. This can reduce gas in the barn, especially when agitating or pumping manure.
  - Modern pit ventilation normally includes continuous fans with at least two vent openings: One to exhaust gases and the other for makeup air.
  - Use explosion-proof fans, because waste gases may be flammable.
  - Locate exhaust vents away from barn doors, windows, and other air intakes.
  - Use emergency generators to keep ventilation systems running during electrical outages. If generators are absent, open doors and windows or move livestock and people outdoors if power fails.

Pumping, draining, agitating, and power washing: Hazardous gases may increase in barns when manure is disturbed. Observe these precautions:

- When agitating or pumping under-barn manure storage, use maximum forced-air ventilation and consider moving people and livestock out.
- For shallow pits, use maximum forced-air ventilation during power washing, plug pulling, and draining. Be prepared to move livestock and people if necessary.
- Manure pits may experience foaming. Hazardous gases trapped in the foam may be released by pressure washing. The Great Plains Center for Agricultural Health (GPCAH) offers the following advice for foaming pits:
  - Schedule pressure washing for times when manure volume is low and foaming is minimal.
  - Following the manufacturer's instructions, turn off pilot lights, heaters, and other ignition sources before pressure washing.
  - Operate ventilation systems during pressure washing and for at least 30 minutes after.
- Do not agitate when manure temperatures are especially high. More gas is released at higher temperatures.

Figure 3.10. Swine barn exhaust fans. Vents that provide clean makeup air are located on the opposite side of the building.

Figure 3.11. Hazardous concentrations of toxic gases can be released from above-ground tanks and lagoons during pumping and agitation. (Credit: USDA)

Contaminants and gas production: Manure gases are produced at higher rates when manure is contaminated with gypsum, silage runoff, spoiled feed, and other sulfur sources. For this reason, many livestock producers have stopped using gypsum in cattle bedding.

Fire safety: Avoid sparks, open flames, or smoking, especially during agitation, plug-pulling, power washing, pumping, and other activities that disturb flammable waste gases.

Reduce the need for entering pits:

- Secure pit covers with hinges so they cannot fall in; alternatively, attach chains to pit covers and hoses so they can be safely retrieved if they fall.
- Ensure pumping equipment is accessible from outdoors; otherwise, attach chains for future retrieval and servicing.

Confined space entry procedures: Do not enter waste storage pits or tanks without approved air monitoring instruments, appropriate respirators, such as a positive-pressure self-contained breathing apparatus or airline respirator, and all components of a permit-required confined space entry program as discussed in Lesson 11.

Discussion

1. Consider the facts and case reports in the earlier part of this lesson:
   a. Describe each area where you may encounter manure gases at your farm.
   b. How are the following issues handled at your farm?
      i. Describe any ventilation used to reduce waste gases in barns.
      ii. Describe any procedures you take to protect workers and animals when waste is agitated, pumped, drained, or flushed with water.
      iii. Describe any extra precautions you take on your farm when manure pits are foaming.
      iv. Describe how people and animals are kept out of waste storage structures on your farm.
      v. Does anyone enter waste storage structures at your farm? If so, describe the procedures they follow.
2. Consider the safety recommendations in the "Protect Yourself and Others" section of this lesson. Discuss any new precautions from this section that you would like to begin taking at your farm.

Quiz Yourself

1. Unless you test the air, always assume that manure pits contain _____.
   a. deadly gases
   b. safe oxygen levels
2. Deaths can be prevented by _____.
   a. holding your breath when you enter a manure pit
   b. staying out of manure pits
3. The most dangerous levels of manure gases are released when waste is _____.
   a. undisturbed
   b. agitated, pumped, flushed with water, or drained
4. It is helpful to _____ ventilation in working areas of barns when under-floor manure pits are being agitated or pumped.
   a. increase
   b. decrease
5. Nearby workers _____ when open-air manure tanks are being agitated
   a. can be killed
   b. cannot be killed
6. During electrical outages _____.
   a. close all barn doors and windows to reduce ventilation
   b. use emergency generators to keep ventilation systems running
7. The safest time to use pressure washers in barns is when manure _____.
   a. is foaming
   b. is not foaming
8. Never enter a manure pit unless you _____.
   a. follow confined space procedures
   b. get in and out in less than one minute

Lesson 4.
Gases in Farm Storage Structures and Wells

Low oxygen and hazardous gases are common in enclosed farm storage structures. These include:

- On-farm storage tanks
- Water wells and cisterns
- Silage fermentation and storage
- Grain storage areas and transport vehicles where fumigants are used
- Controlled atmosphere storage rooms

Farm operators should evaluate these areas to identify hazards. A permit-required confined space program may be needed when anyone enters these areas, as discussed in Lesson 11.

On-farm Storage Tanks

Farmers use tanks to store agricultural products, by-products, feed supplements, lubricants, and fuels. Hazards in tanks include low oxygen, toxic gases or vapors, and liquids that cause drowning.

Case reports

Here is a sample of cases that illustrate how workers have been injured in tanks when precautions were not observed.

Figure 4.1. Storage tanks for fuel, feed supplements, agricultural products, and other substances may contain hazardous gases and low oxygen concentrations. (Credit: CDC Public Health Image Library)

Dairy farm workers suffocate inside molasses tank. Two workers climbed down into a horizontal storage tank. They were planning to clean a residue of molasses feed supplement that had been in the tank for several months. Unknown to them, there was not enough oxygen in the tank to support life. Both workers collapsed and died of asphyxia soon after entering the tank. Sources: *OSHA Inspection 308878636* and U.S. Environmental Protection Agency. (2011). *Safety practices for on-farm anaerobic digestion systems*.

Figure 4.2. Low oxygen levels and hazardous gases are common in water wells and cisterns.

Figure 4.3. Silage storage structures may contain hazardous fermentation gases. Grain storage structures may contain fumigants.

Worker dies inside liquid whey feed supplement tank. A farm maintenance worker climbed in through the top of a 12-foot-tall polyethylene tank to open a broken ball valve. The tank contained liquid whey that was added to animal feed. The worker lost consciousness inside the tank and died from asphyxiation due to low oxygen and likely high levels of fermentation gases. Source: *OSHA Inspection 1085311.015*.

Farmer dies from toxic gas while cleaning bulk milk tank. A farmer was cleaning inside a 1,500-gallon bulk milk tank with a paste made of cleaning granules and well water. The well water contained high levels of naturally occurring hydrogen sulfide. Hydrogen sulfide is a poisonous gas produced by bacterial action and other natural processes. At low concentrations, it has a "rotten egg" smell. At higher concentrations, it may have no noticeable odor. Gas from the water accumulated inside the tank, and the farmer died from hydrogen sulfide exposure within 20 minutes of entering. Source: *OSHA Inspection 1403966.015*.

Workers die in compost runoff tank. Two workers entered an underground compost runoff storage tank and were asphyxiated. Source: *OSHA Inspection 102699709*.

Protect yourself and others around farm tanks

- Keep tank covers locked.
- Do not enter a tank unless you follow confined space precautions discussed in Lesson 11.

Figure 4.4. Farm storage tanks often contain low oxygen and hazardous gases.

Figure 4.5. Even water tanks (shown here in black) may contain oxygen-deficient air.

Figure 4.6. The gas monitor at left shows just 16.6% oxygen in the air of the irrigation water structure at right. Normal air contains 20% to 21% oxygen. Concentrations below 19.5% are oxygen deficient and potentially hazardous.

Water Wells and Cisterns

Wells and cisterns provide water for livestock, human consumption, and irrigation. The air in a well or cistern is often low in oxygen. This air may also contain poisonous gases from microbial action and other natural processes.

Case reports

These cases describe tragedies that have happened when workers entered wells or cisterns without proper precautions.

Worker asphyxiated in well. A worker entered the underground vault of a domestic well to check the water level. The air was low in oxygen, and the worker died from asphyxiation. Source: *OSHA Inspection 125897140*.

Hydrogen sulfide gas kills two workers in cistern. Two workers entered a concrete cistern. Unknown to them, hydrogen sulfide gas was present in the cistern's air space. The workers were overcome and died of hydrogen sulfide poisoning. Source: *OSHA Inspection 106278914*.

Low oxygen in irrigation standpipe takes worker's life. A worker entered a 12-foot-high, 3-foot-diameter irrigation standpipe to repair a valve. He died of asphyxia due to low oxygen levels in the pipe. Source: *OSHA Inspection 111942371*.

Farm worker killed by toxic gas in storm drain. A farm worker was cleaning debris inside a storm-drain shaft. The shaft was 2 feet in diameter and 10 feet deep. While standing on a ladder inside the shaft, he collapsed and fell to the bottom. Another worker tried to rescue him but also collapsed. Emergency responders came and retrieved both men from the shaft. The first worker was pronounced dead at the hospital. The second was placed on life support. Tests found high levels of hydrogen sulfide in the shaft. Source: *OSHA Inspection 315072645*.

Protect yourself and others around water wells and cisterns

- Keep well and cistern covers locked.
- If it is necessary to enter a well or cistern, follow confined space precautions as discussed in Lesson 11.

Fumigants in Commodity Storage Areas and Transport Vehicles

Stored commodities may be treated with fumigants to control insects, rodents, and other pests. At high concentrations, fumigants may cause illness and injury in humans.

Case report

Consider the case of two workers who were injured when they disturbed a load of feed that was being fumigated.

Workers sickened by fumigant. Two workers removed a tarp from a truckload of animal feed that had been fumigated with phosphine-producing tablets two days before. Soon after removing the tarp, both workers experienced nausea, cramps, and vomiting. *Phosphine is a poisonous gas. It can be applied from a canister or produced from pesticide tablets scattered in the storage area.* Source: O'Malley, M. (1998). Injuries and illnesses associated with exposures to phosphine and phosphine decomposition products. *California Environmental Protection Agency Report HS-1756*.

Figure 4.7. Do not open doors or remove tarps if you see this sign posted near stored grain, unless you are a trained pesticide handler with the proper protective equipment.

Protect yourself and others around fumigated grain

Unless you are a trained pesticide handler with the proper protective equipment, do not open doors or remove tarps if you see signs indicating a fumigation has taken place. If you experience symptoms of overexposure after entering an area where pesticides were recently used, call the Poison Help line and follow their instructions. The nationwide poison helpline is 1-800-222-1222.

Silage Fermentation and Storage

Silage is a nutrient-rich animal feed made by fermenting moist plant materials in low-oxygen storage. Silage is often made from alfalfa, oats, or corn. Farmers use it to feed ruminants such as cattle and sheep. Silage is fermented and stored in various types of silos. Examples include upright silos, bunker silos (piles or trenches), and bag silos.

When a silo is filled, fermentation processes create large amounts of toxic gases. Two of the most dangerous silo gases are nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4, often called simply

Figure 4.8. Upright concrete stave silos are usually loaded and unloaded from the top. The top may not be sealed from outside air, so a "cap" of plastic sheeting may be used to keep out as much air as possible.

Figure 4.10. Pile silos store silage on the ground. Silage is covered with plastic sheeting to keep out the air. (Credit: Agricultural Research Service)

Figure 4.9. Upright oxygen-limiting silos (blue in the image) are normally loaded from the top and unloaded from the bottom. They are designed to maintain a nearly airtight environment. (Credit: Lynn Betts, USDA Natural Resources Conservation Service)

Figure 4.11. Bag silos pack silage into durable plastic bags that create a nearly airtight environment. Some bags are small, while others may reach hundreds of feet in length.

nitrogen tetroxide). These corrosive gases damage the lungs and may even lead to death. The full effects of exposure may not be felt for hours, so farmers often continue working in the gas, not knowing they are being harmed.

Silos produce many other hazardous gases. Many are invisible, odorless, and undetectable without special monitors. Some, like carbon monoxide, are highly poisonous. Others, like carbon dioxide, can displace oxygen and cause suffocation. In many silo injuries and deaths, it is unclear which gases were responsible. Some, like methane and carbon monoxide, can also cause fires or explosions.

Case reports

Farmers and livestock have been injured by silo gases while:

- entering silos.
- opening silo hatches without fully entering the silo.
- climbing ladders in silo chutes, even without opening hatches.
- breathing air just outside a silo.

Here is a sample of cases that illustrate how these injuries can happen.

Hazards of entering freshly filled silos

Dairy farmer permanently disabled by gases in an upright silo. A healthy, non-smoking 63-year-old dairy farmer climbed the chute of a silo two days after it was filled. He noticed the gas while climbing, but he was able to enter the silo and work with little discomfort. Later that night, he began feeling ill. He went to a hospital the next day, complaining of wheezing, sweating, and weakness. He soon developed a fever, became semi-conscious, and his skin turned blue. X-rays showed fluid in his lungs, and doctors diagnosed him with "silo-filler's disease" from breathing nitrogen dioxide. He was treated with corticosteroids and other medications. His condition improved, but he had a relapse a few weeks later. He responded to further treatments but continued to suffer from shortness of breath. *Doctors have recorded many similar cases. Outcomes vary from complete recovery to permanent disability or even death*. Source: Horvath, E. P., doPico, G. A., Barbee, R. A., & Dickie, H. A. (1978). Nitrogen dioxide-induced pulmonary disease: Five new cases and a review of the literature. *Journal of Occupational Medicine, 20*(2), 103-110.

Two boys asphyxiated in oxygen-limiting silo. Two 16-year-old boys were repairing breather bags at the top of an upright oxygen-limiting silo. Breather bags expand and contract to control pressure in a sealed silo when temperatures fluctuate. The silo had been filled with shredded alfalfa three days earlier. Unknown to adults, the boys climbed the ladder and entered the hatch at the top of the silo. They were quickly overcome by gases and collapsed on the silage. By the time they were found, the boys had been dead for some time and could not be revived. The coroner's report stated they died from asphyxiating gases. *In this case, deaths may have been caused by a lack of oxygen or by poisonous gases such as nitrogen dioxide and carbon monoxide.* Source: National Institute for Occupational Safety and Health. (2008). *Two teen workers asphyxiate in an agricultural silo*. FACE Report 03WA038.

Hazards of working near freshly filled silos

Farmer injured by gases near a silo. A 67-year-old farmer was feeding cattle near a silo that contained fresh corn silage. There was an irritating yellow haze in the air. He soon felt weak, and his body began to ache. He continued to feel worse throughout the day and quit working around 4 p.m. That night, he developed a severe cough with occasional blood. The next morning, he was short of breath, his chest hurt when he coughed, he was dizzy, and he had no appetite. When he sought medical attention, his temperature was high, and doctors discovered fluid in his lungs. He was hospitalized and underwent treatment that included corticosteroids and antibiotics. He recovered and was discharged from the hospital after 20 days. Follow-up examinations suggested he made a full recovery. His illness was classified as acute chemical bronchopneumonia caused by silo gas. Source: Cornelius, E.A., & Betlach, E.H. (1960). Silo filler's disease. *Radiology, 74,* 232-238.

Cattle killed by cloud of gas emitted from silage bunker. A cloud of reddish-brown gas escaped from under the plastic sheeting of a horizontal silage

bunker. The gas was seen entering a cubicle house for dairy cows. Eleven cows suffered lung damage, and three died from the exposure. *Silo gases don't just affect humans. In this case, cattle were affected by gases that drifted from a nearby silo to the building where they were housed.* Source: Verhoeff, J., Counotte, G., & Hamhuis, D. (2007). Nitrogen dioxide (silo gas) poisoning in dairy cattle. *Tijdschr Diergeneeskd*, *132*(20), 780-782.

Facts about hazardous gases in and near silos

- All types of silos (conventional, oxygen-limiting, bunkers, bags, etc.) produce hazardous gases.
- Silo gases are sometimes visible as a yellow, orange, or brown haze. This haze may contain dangerous concentrations of nitrogen dioxide and nitrogen tetroxide. These gases can be present from the day a silo is filled until several days or weeks afterward.
- Some silo gases, like carbon monoxide, methane, and carbon dioxide, cannot be seen. These invisible, odorless gases may be present at deadly concentrations in a silo for several weeks.
- Concentrations of hazardous gases diminish over time, but oxygen levels may remain low indefinitely. Never enter a silo without taking adequate precautions, as discussed in Lesson 11.

Protect yourself and others from silage gases

- When filling upright silos, adjust spreaders to distribute the silage uniformly. This will minimize the need to enter the silo for manual leveling.
- For bunker silos, use enough weight on the plastic sheeting to minimize leaks of toxic gases.
- Place silage bags and storage structures away from barns and areas with people or livestock. This helps prevent silo gases from drifting into occupied areas.
- Do not park near any type of silo on the day of filling and for at least two weeks afterward. If you do find your vehicle engulfed in silo gases, stay away until there is no sign of gas remaining. Once the air is clear, turn a strong blower on the vehicle. You can use the blower of the silage harvester. With the blower running, carefully open the vehicle doors, trunk, and other compartments. Continue ventilating for some time so gases can dissipate from all spaces in the vehicle before you enter it.
- Detach and move silage bagging equipment away from bags overnight and during long breaks to prevent engulfment in poisonous gases.
- Keep doors closed between barns and any attached or nearby silos that have been recently filled.

Figure 4.12. Yellow or brown oxides of nitrogen can often be seen near freshly filled silage structures. The gases are highly toxic to humans and other animals.

Figure 4.13. Do not park near freshly filled silage structures. Drifting toxic gases may prevent access to the vehicle.

- Keep children and animals away from recently filled silos and attached feed rooms. Use locks and signs to keep people out.
- Keep windows open and use fans to ventilate any feed rooms attached to silos. Continue ventilating feed rooms for at least two to three weeks after the attached silos have been filled.
- For the first few weeks after filling, it will be especially dangerous to enter a silo. Although oxides of nitrogen are sometimes detected by their color or bleach-like odor, there are no warning signs when oxygen concentrations are low or when carbon monoxide is at harmful levels.
- Even after the initial period of greatest danger, follow these precautions if you need to enter an upright silo:
  - Observe all requirements of a permit-required confined space entry program as discussed in Lesson 11.
  - Use a strong blower, such as the blower of a silage loader, to ventilate the silo for at least 30 minutes before entering. Keep the blower running while inside, and use a flexible drop-down tube if the headspace is large.
  - Have an observer ready to call for help in an emergency.
  - Exit the silo immediately if you experience coughing, trouble breathing, faintness, or other difficulties.
  - If someone collapses or struggles inside a silo, call 911. Do not enter to attempt a rescue unless you have special equipment and training, as described in Lesson 11.
- Seek immediate medical attention if you are exposed to silo gases. The full effects may take hours, days, or weeks to appear. Early treatment is the most effective
- Conditions during the growing and harvest seasons affect the production of gases during fermentation. Adjust practices accordingly:
  - Weedy and damaged crops may absorb excess nitrates from the soil. This can lead to increased nitrogen oxides in silos. Use integrated pest management to control weeds, damaging insects, and crop diseases. Harvest immediately after any hail or frost damage to prevent excess nitrate uptake.
  - Heavily fertilized crops can produce more oxides of nitrogen. Apply balanced fertilizers based on soil analysis but do not overfertilize.
  - When it rains after a drought, crops may absorb more nitrates from the soil. Harvest before the rain or wait at least five days after it stops.
  - Nitrates may concentrate in the lower 1 foot of corn stalks. Cut higher than usual when crops are stressed.

Figure 4.14. Do not leave silage baggers attached to bags overnight or during long breaks. The air monitor at left shows a deadly concentration of 20 parts per million (20 ppm) nitrogen dioxide near the entrance to the bagger. For reference, nitrogen dioxide concentrations of just 13 ppm are considered immediately dangerous to life and health (IDLH).

Controlled Atmosphere Storage Rooms

Harvested produce is often stored in sealed rooms where gases like nitrogen and carbon dioxide displace oxygen and delay spoilage. Oxygen in these rooms may be reduced to 2% or 3%, low enough to cause unconsciousness in seconds and death within minutes.

Normal outdoor air contains about 20% to 21% oxygen, 75% to 78% nitrogen, 0 to 4% water vapor, 1% argon, and small amounts of trace gases. Oxygen levels below 19.5% are hazardous and classified as oxygen deficient. Never enter a controlled atmosphere storage room without first checking air monitors to ensure the oxygen level is safe.

Case report

The following case illustrates the dangers of entering a controlled atmosphere storage room under low oxygen conditions.

- An orchard worker planned to gather apples from a controlled atmosphere storage room where the oxygen concentration was reduced to 1.6%. He took a deep breath, held it, and entered. He made it just 7 feet before collapsing. A visitor tried to rescue him but also collapsed. Others came and managed to pull both men from the room. Emergency responders revived the worker who first collapsed, but the visitor did not survive. Source: *OSHA Inspection 309602738*.

Figure 4.15. Controlled atmosphere storage rooms (the large white chambers in the image) reduce oxygen levels to preserve agricultural products. (Credit: Agricultural Research Service)

Protect yourself and others around controlled atmosphere storage rooms

Follow these precautions to prevent injuries and deaths.

- Keep entrances to controlled atmosphere storage rooms securely locked.
- Install oxygen monitors at various locations in the room, with displays that can be read from outside.
- Establish an opening procedure for each controlled atmosphere storage room. Include at least the following precautions:
  - Confirm that all inert gas lines have been shut off.
  - Ventilate with fresh air.
  - Use air monitors to confirm the oxygen level is acceptable throughout the room.
  - A sealed room may be deficient in oxygen, even if it has not been intentionally drawn down. This means established procedures must be followed each time the room is opened.
  - Post a checklist of precautions for authorized entry at each entrance and post signs warning unauthorized persons not to enter.
  - Instruct personnel not to attempt rescues unless trained and equipped with appropriate gear.
  - Evaluate each room to determine if it qualifies as a confined space. Observe permit-required confined space entry procedures if required (see Lesson 11).

Figure 4.16. Never enter a controlled atmosphere storage room without testing the oxygen levels and following an established opening procedure. (Credit: Agricultural Research Service)

Discussion

1. Describe any of the following structures that exist at your workplace:
   a. Tanks for storing agricultural products, by-products, feed supplements, lubricants, and fuels.
   b. Wells and cisterns.
   c. Grain storage areas and transport vehicles where fumigants are used.
   d. Silage fermentation and storage.
   e. Controlled atmosphere storage rooms.
2. Complete the following for each type of structure you described above:
   a. Read the sections in this lesson that address the type of structure.
   b. Describe any precautions already in place at your workplace to protect against gases in these structures.
   c. Based on the recommendations in the "Protect Yourself and Others" sections for each type of structure, describe any additional precautions you would like to start taking.
   d. How confident are you that you have, or can get, the equipment and knowledge to take these precautions?

Quiz Yourself

1. Water wells, cisterns, and on-farm storage tanks _____ dangerous gases.
   a. may contain
   b. never contains
2. When you see fumigation signs at a grain storage area, _____.
   a. open all doors and remove tarps to provide ventilation.
   b. do not open doors or remove tarps unless you are a trained pesticide handler with proper protective equipment.
3. Poisonous gases _____ in and near upright silos.
   a. may occur
   b. never occur
4. Poisonous gases _____ near silo bags and bunkers.
   a. may occur
   b. never occur
5. A yellow, orange, or brown fog near a silo _____.
   a. is safe to breathe
   b. is poisonous
6. Procedures for opening a controlled atmosphere storage room include _____.
   a. leaning in the open doorway to take a test breath before entering
   b. using air monitors to confirm oxygen is normal before entering
7. Special confined space procedures _____ when entering farm storage tanks, wells, cisterns, and upright silos.
   a. may be required
   b. are never required

Lesson 5.
Pesticide Restricted Entry Intervals and Application Exclusion Zones

Crops may be treated with a variety of pesticides, such as herbicides, insecticides, and fungicides. Overexposure to pesticides can make you ill. Pesticides enter your bloodstream when you touch recently sprayed plants and surfaces, breathe contaminated air, touch your lips with contaminated hands, or eat contaminated food.

To protect workers, each agricultural pesticide label specifies a restricted entry interval (REI). The sign in Figure 5.3 must be posted during the restricted entry interval, and workers must stay out of treated areas during this time:

Besides the restricted entry interval, there may also be an application exclusion zone (AEZ) while a pesticide is being applied. Only trained pesticide handlers with proper protective equipment should be within the AEZ during treatment. There are some exceptions for farm family members inside closed shelters.

Figure 5.1. Unless you are a trained pesticide applicator with the required protective equipment, stay away from areas where pesticides are being applied. (Credit: Agricultural Research Service)

Case Reports

The following cases illustrate how workers have been injured when they entered treated areas during restricted entry intervals.

Worker suffers overexposure to insecticide in treated field. A worker entered a field that was recently sprayed with an organophosphorus insecticide. She quickly developed signs and symptoms of overexposure, including headache, fast heart rate, anxiety, breathing trouble, confusion, and excessive sweating. Source: Division of Environmental Health, Michigan Department of Community Health. (2014). *Pesticide Illness and Injury Surveillance in Michigan 2012.*

Figure 5.2. Ask your supervisor about any recent pesticide applications before entering fields and greenhouses. (Credit: Agricultural Research Service)

Figure 5.3. Unless you are a trained pesticide handler with proper protective equipment, stay out of fields, greenhouses, and other growing areas whenever you see this sign.

Worker sickened after entering greenhouse where herbicide had just been applied. A worker entered a greenhouse two or three hours after an herbicide had been applied. She suffered symptoms of overexposure, including headache and vomiting. Source: *OSHA Inspection 313480170*.

Call the poison helpline if you have symptoms after entering an area where pesticides were recently used. The nationwide Poison Help line is 1-800-222-1222.

Discussion

1. What agricultural pesticides are used in fields, greenhouses, and other growing areas on your farm? What are some hazards of these pesticides?
2. How is information about pesticide applications shared with workers at your farm?
3. What procedures are followed at your farm for restricted entry intervals?
4. Read all the information in this lesson and discuss any new procedures your farm may need for REIs or AEZs.

Quiz Yourself

1. If you see this sign posted at a field or greenhouse, do not enter unless _____.

   a. you are a trained pesticide handler with proper protective equipment
   b. you are wearing a respirator, Tyvek suit, and neoprene gloves

Lesson 6.
Anhydrous Ammonia for Field Applications and Commodity Storage

Anhydrous ammonia is injected into the soil as a fertilizer. It is also used to control mold growth in high-moisture grains and hay.

Appearance: Anhydrous ammonia is a colorless gas, but it may appear as a fog at high concentrations. It has a sharp odor similar to smelling salts or ammonia-based cleaners.

Field tanks: Anhydrous ammonia is often stored in field application tanks or nurse tanks. It is compressed into a liquid, with gas in the headspace of the tank.

Leaks: Pressurized ammonia can spray 10 to 20 feet from a leak in a pressurized tank or hose.

Cold temperatures: Liquid anhydrous ammonia vaporizes quickly when released from a tank. This transition cools the gas to subzero temperatures that can freeze skin and other tissues on contact.

Application: Hose assemblies transfer ammonia from tanks to the application toolbar, where the ammonia is injected into the soil through knives.

Chemical burns and lung injuries: Anhydrous ammonia is chemically attracted to water in human tissues. It causes alkali burns to moist membranes of the nose, mouth, throat, lungs, eyes, and skin. Severe frostbite is also possible. This lesson focuses on the hazards of breathing ammonia during fertilizer applications.

Case Reports

Here is a sample of cases that illustrate how workers have been injured when precautions were not observed.

Agricultural worker inhales ammonia when hose coupling comes loose. A healthy, nonsmoking 28-year-old man was working with a tank of anhydrous ammonia fertilizer. Suddenly, a hose coupling came loose, and he inhaled ammonia gas deeply into his lungs. He was taken to a hospital, where doctors first noticed chemical burns to his face and the mucus membranes of his nose and throat. Within a few hours, he experienced respiratory distress with a buildup of fluid and a collapse of some lung segments. A tracheostomy became necessary as his large airways began to close. He required intravenous feeding for the next 20 days, with antibiotics to fight a variety of infections. He survived but continued to suffer from obstructive airway disease resulting from the expo-

Figure 6.1. Hoses deliver anhydrous ammonia fertilizer from the white field tanks to the blue application toolbar behind this tractor.

Figure 6.2. Pressurized anhydrous ammonia can cause severe chemical burns to the respiratory system, eyes, mouth, and skin.

First Aid for Anhydrous Ammonia Exposures

Skin. Anhydrous ammonia causes severe chemical burns and frostbite. Do not pull off frozen clothing; it may stick and pull away damaged skin. If your skin is exposed to anhydrous ammonia, wash or soak in fresh water for at least 15 minutes. Get to a doctor immediately. If possible, continue flushing with fresh water while traveling to the doctor. Do not apply ointments.

Eyes. Anhydrous ammonia causes severe eye burns and may lead to blindness. Wear unvented goggles or a full-face respirator with appropriate cartridges when connecting or disconnecting hoses. If your eyes are exposed, flush with fresh water for at least 15 minutes and seek immediate medical attention. Continue flushing with fresh water while traveling to the doctor.

Lungs and upper airways. Anhydrous ammonia causes severe burns to the respiratory tract. This may lead to permanent lung injury or even death. If you breathe anhydrous ammonia, get to fresh air quickly. See a doctor if you have severe coughing, shortness of breath, airway blockage, or other serious effects.

Digestive system. If liquid ammonia is swallowed and the victim is conscious, drink large amounts of water and see a doctor immediately. Do not induce vomiting or further damage may occur. Do not give liquids to anyone who is unconscious.

sure. *Make sure all couplings and connections are secure before opening valves.* Source: Taplin, G. V., Chopra, S., Yanda, R. L., & Elam, D. (1976). Radionuclidic lung-imaging procedures in the assessment of injury due to ammonia inhalation. *Chest, 69*(5), 582-586.

Farm mechanic cuts pressurized hose with knife. A farm mechanic was removing an anhydrous ammonia tank and application rig from a tractor. He was suddenly sprayed with ammonia when he cut through a hose with a knife. After irrigating his eyes, he was driven to a hospital burn unit. He was hospitalized for more than a month with eye and lung injuries. *Treat all closed equipment as though it is pressurized with ammonia, especially when exposed to warm temperatures or sunlight.* Source: *OSHA Inspection 120201264*.

Worker killed when pulling away from fill station without disconnecting tank. A worker pulled an ammonia nurse tank away from a fill station without disconnecting the fill pipe. The pipe broke, releasing a massive amount of anhydrous ammonia. Disoriented, he drove in a circle back to the fill pump, where the tractor engine died. He plunged himself into a stock tank filled with water for emergencies, but his injuries were too severe. The attending physician stated he died of chemical asphyxiation. *Park on level ground and block the wheels to prevent movement when filling tanks. When finished, walk around the equipment to verify hoses have been disconnected before moving the tank.* Source: *OSHA Inspection 104592324*.

Worker injured by ammonia spray while tightening pressurized fitting. A worker noticed a small leak coming from a coupling of an anhydrous ammonia tank. He tried to tighten the coupling without relieving pressure. The coupling popped off and sprayed him with ammonia. The inhaled vapors caused serious damage to his respiratory system, requiring a tracheostomy and hospitalization. *Close valves and relieve pressure before attempting any repairs.* Source: *OSHA Inspection 1318970.015*.

Protect Yourself and Others

The following precautions are suitable for farm applications of anhydrous ammonia fertilizer. If you own or fill your own tanks from bulk storage, you will need additional information and training. Purdue University has published the following helpful guide: *https://ag.purdue.edu/department/extension/ppp/resources/ppp-publications/ppp-140.html*

Federal age restrictions: Nonfamily youth under age 16 are not allowed to transport, transfer, or apply anhydrous ammonia in agriculture.

Emergency water supply: Have fresh water available to flush exposed tissues, as follows:

- Have at least 5 gallons of water available on the nurse tank.
- Keep another 5 gallons or more on the tractor.
- Have a 6- to 8-ounce squeeze bottle in the cab for immediate use as you make your way to the 5-gallon containers.
- Change water daily. Water absorbs ammonia from the air and loses some of its effectiveness after a day in the field.

Protective equipment:

- ***Respirator:*** A full-face respirator with anhydrous ammonia cartridges will help you escape sudden releases when connecting hoses. For intense or prolonged exposures, you will need a self-contained breathing apparatus (SCBA) and a full-body protective suit.
- ***Goggles:*** Use unvented goggles to protect your eyes when not wearing a full-face respirator. Vented goggles and safety glasses will not protect your eyes from ammonia gas.
- ***Protective gloves:*** Protect your hands with heavy nitrile or neoprene gloves that have an internal lining.
- ***Work clothing:*** Wear a heavy, long-sleeved shirt and long pants or coveralls to help reduce skin exposure.

Pressure relief: Stay away from pressure-relief valves unless you are wearing protective equipment. Daytime heating causes ammonia to expand inside the tank, hoses, and application equipment. This increases the internal pressure and may trigger a valve to release gas.

Inspect equipment before each use:

- ***Tank:***
  - Consult the tank supplier or manufacturer if you notice any rust, dents, illegible markings, or other damage.
  - Make sure the pressure gauge readings are within the manufacturer's specified normal range.
  - Use fittings approved for anhydrous ammonia.
  - Make sure the tank, fittings, valves, and gauges are serviced according to the manufacturer's recommendations.
- ***Running gear:***
  - Use a safety clip on the hitch pin.
  - Make sure safety chains and hooks are properly attached.
  - Check tires for proper air pressure, adequate tread, and lack of damage.
  - Service the running gear regularly, following the manufacturer's recommendations.

Figure 6.3. Wear protective equipment and follow the tank manufacturer's instructions when attaching or removing anhydrous ammonia hoses.

- ***Hoses:***
  - Use hoses that are approved for pressurized anhydrous ammonia.
  - Make sure hoses are the proper length to prevent sags where ammonia could accumulate.
  - Avoid hanging hoses over equipment edges that could cause deformation or damage.
  - Make sure hoses and connectors are in good condition and properly attached.
  - Replace hoses according to the manufacturer's schedule.
  - Store hoses vertically in the off-season.
- ***Applicator knives:***
  - To reduce unintended plugging, ensure applicator knives are undamaged and in good condition.
  - Wear protective equipment and observe the manufacturer's instructions for relieving pressure before clearing plugged knives or metering screens.

Attaching and removing hoses:

- Attach the nurse tank hose to a parking fitting when not in use.
- Follow the manufacturer's recommendations for connecting and disconnecting breakaway couplers. This usually involves the following steps to relieve pressure:
  - Wear gloves and unvented goggles or a full-face respirator with anhydrous ammonia cartridges.
  - Stand upwind or crosswind of the connection so any released gases blow away from you.
  - Operate valves and bleeders slowly in the manufacturer's specified order. Keep the hose ends and valve openings pointed away from you.
  - Make sure no one is in the way before venting the pressure relief valve.
  - Clean the coupler fittings so they are free from soil and debris once the ammonia has been drained.
  - Follow the manufacturer's instructions for bleeders, valves, and leak checks when reattaching couplers.
  - Carry hoses by the coupling or valve body and not by the control handle; otherwise, the handle could turn and open the valve unexpectedly.
  - Contact the manufacturer for replacement instructions if the original copy is lost.

Transportation laws: Laws for transporting ammonia on public roads differ from state to state. Your farmer's cooperative will typically have a copy of the most current rules. In Kansas, you can also consult the Kansas Highway Patrol or the Kansas Corporation Commission's Transportation Division. Tanks typically operate at 25 mph or slower and require a slow-moving vehicle sign (SMV) and special markings.

Emergency response: Anhydrous ammonia may behave unpredictably after an accidental release. Ammonia vapors may first rise and then sink back toward the ground and drift with the wind. For large leaks, call 911, keep people away, and wait for trained emergency responders.

Discussion

1. How is anhydrous ammonia application equipment supplied, serviced, filled, and inspected at your farm?

2. Describe any emergency water and first aid supplies kept on tractors and application equipment at your farm.

3. Describe any protective equipment you wear and the situations when you wear it. Include any work clothing, protective gloves, goggles, or respirators that you use.

4. From the first part of this lesson, consider the information about anhydrous ammonia, its health effects, first aid, and the case studies. Discuss the following:
   a. What do you believe are the main situations when a worker might be exposed to anhydrous ammonia at your workplace?
   b. How confident are you that you have (or can get) the equipment and knowledge to protect yourself while working with anhydrous ammonia or while responding to emergencies? Explain.

5. Consider the safety recommendations in the "Protect Yourself and Others" section of this lesson.
   a. Explain at least three anhydrous ammonia safety recommendations that you feel are most important for the work you do.
   b. Discuss any possible areas for improvement at your workplace.

Quiz Yourself

1. Anhydrous ammonia is strongly attracted to _____.
   a. dry skin and tissues
   b. moist skin and tissues

2. Youth who are not farm family members must be at least ___ years old to work with anhydrous ammonia.
   a. 14
   b. 16

3. Wear a/an _____ when connecting or disconnecting anhydrous ammonia hoses.
   a. N95 dust mask
   b. full-face respirator with ammonia cartridges

4. Emergency first-aid water should be replaced _____ when applying anhydrous ammonia in the field.
   a. daily
   b. weekly

5. Pressure-relief valves may unexpectedly release anhydrous ammonia when the tank and hoses _____.
   a. heat up
   b. cool off

Lesson 7.
Hazardous Exhausts from Engines and Appliances

Fuel-burning engines and appliances release harmful gases and particles. Proper maintenance and outdoor venting help protect your health. Here are some key facts:

Carbon monoxide is a poisonous gas produced when fuels burn. It has no odor and is invisible. A carbon monoxide detector is the only way to know when dangerous levels of the gas are present.

- ***Health effects:***
  - Carbon monoxide interferes with the body's ability to use oxygen. Severe exposures may cause death or lasting damage to the brain, heart, and other organs.
  - High levels of carbon monoxide are dangerous for everyone.
  - Even low levels can be hazardous for children, the elderly, unborn babies, and people with heart conditions.
- ***Warning signs:***
  - Early warning signs of poisoning may include dizziness, nausea, sleepiness, headache, and tightness or pain in the chest.
  - At higher concentrations, there may be vomiting, confusion, and weakness.
  - At very high concentrations, a person may collapse with no warning.
- ***Common sources:***
  - **Engines:** Carbon monoxide is produced by engines that burn gasoline, diesel fuel, and LP gas. This includes small equipment such as lawn mowers, power washers, and generators. It also includes large machines such as

Figure 7.2. Carbon monoxide and other poisonous gases are produced by fuel-burning appliances such as furnaces and water heaters.

Figure 7.1. Combustion engines, such as the propane engine of this forklift, emit carbon monoxide, oxides of nitrogen, and other hazardous gases in poorly ventilated buildings and trailers.

Figure 7.3. Fuel-burning space heaters of any size can produce hazardous levels of carbon monoxide when operated indoors without proper venting.

automobiles, tractors, combines, skid-steer loaders, and forklifts.

- **Appliances:** Carbon monoxide is produced by appliances that burn fuels such as natural gas, wood, kerosene, propane, heating oil, and charcoal. This includes space heaters, furnaces, stoves, ovens, water heaters, boilers, air compressors, and fireplaces.

Other hazardous exhaust gases include oxides of nitrogen and sulfur dioxide.

Soot and other particles in exhausts are known to cause lung damage and other health effects.

Figure 7.4. Small engines can create hazardous levels of carbon monoxide while running in repair shops and other indoor spaces.

Figure 7.5. Install carbon monoxide alarms in buildings where fuel-fired appliances are used.

Case Reports

Workers may be exposed to hazardous exhaust whenever fuel-fired equipment is not properly ventilated. Here is a sample of cases that illustrate how this can happen.

Farmer poisoned by carbon monoxide while using gasoline-powered pressure washer indoors. A 33-year-old farmer used an 11-horsepower washer to clean a swine farrowing room. The room's door was closed, and there was no ventilation. He was overcome after just 30 minutes. The cause of death was carbon monoxide poisoning. Source: Centers for Disease Control and Prevention. (1993). Unintentional carbon monoxide poisoning from indoor use of pressure washers–Iowa, January 1992-January 1993. *Morbidity and Mortality Weekly Report,42*(40):777-779, 785.

Worker killed by tractor exhaust in closed shop building. A farm worker died of carbon monoxide poisoning. He was repairing a tractor hitch in a closed shop while the tractor was running. Source: *OSHA Inspection 1393075.015.*

Farm worker asphyxiated by unvented water heater. A farm worker was using the bathroom where an unvented LP gas water heater was located. He lost consciousness, was found unresponsive, and could not be resuscitated. The cause of death was asphyxia. Source: *OSHA Inspection 305712622*.

Farm worker killed, another injured, by carbon monoxide from portable generator. Two workers were found unresponsive in a greenhouse where a propane generator had been running. One of the workers was hospitalized, and the other died. Carbon monoxide poisoning was found to be the cause of death. Source: *OSHA Inspection 1494511.015*.

Farm workers overcome by carbon monoxide from forklift. A forklift operator and his helper were using a propane-fueled forklift to load pallets of blackberries into a 53-foot over-the-road trailer. Both were overcome by carbon monoxide. The forklift operator died from the exposure. The helper was hospitalized. Source: *OSHA Inspection 317128320*.

Protect Yourself and Others

Fixed appliances must be vented outdoors according to the manufacturer's instructions. This includes fuel-burning furnaces, space heaters, water heaters, boilers, and cooking equipment. Locate flue exhausts away from building air intakes. Inspect and maintain appliances as recommended by the manufacturer.

Portable equipment should be operated outdoors and away from open windows, doors, and building air intakes. This applies to large and small fuel-burning equipment. Examples include automobiles, farm machinery, mowers, power washers, generators, water pumps, and air compressors. If engines must be operated inside, open all doors and windows, and turn on exhaust fans. Better yet, attach a fan-powered exhaust hose system to the tailpipe.

Charcoal and open flames should not be used in buildings, trailers, or tents unless vented outside.

Electric equipment does not emit carbon monoxide. Consider switching to electric equipment in dry indoor locations. Examples include electric power washers, air compressors, space heaters, and forklifts.

Carbon monoxide detectors should be installed if fuel-burning equipment is used indoors. Test, maintain, and replace detectors as recommended by the manufacturer.

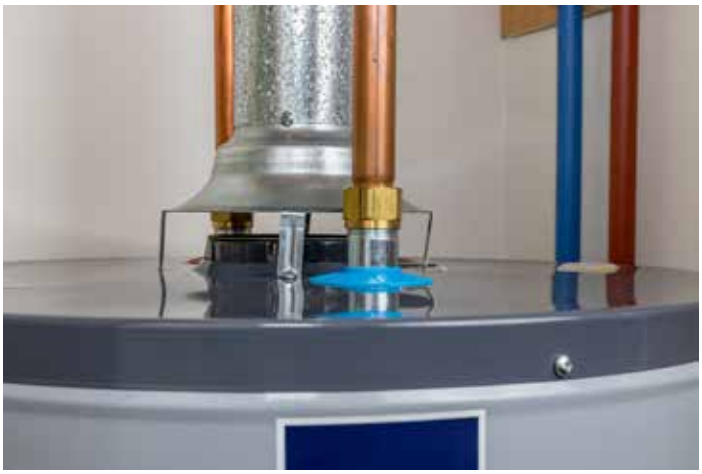

Figure 7.6. Fuel-burning appliances should have flues to exhaust combustion gases outdoors. As an example, note the galvanized flue that rises above the top of this water heater.

Figure 7.8. Install carbon monoxide alarms and increase ventilation if engines are allowed to run while making repairs indoors.

Figure 7.7. Flues from fuel-burning appliances should exhaust combustion gases away from outdoor air intakes.

Figure 7.9. Tailpipe-exhaust extraction systems can be clamped to the tailpipe of machinery during maintenance and repair in indoor spaces.

Carbon monoxide emergencies:

- If a carbon monoxide alarm sounds, stop work and get to fresh air immediately.
- If someone collapses or struggles and you suspect carbon monoxide, call 911. Do not enter the hazardous area or try a rescue on your own. Special supplied-air respirators and rescue equipment are required.
- If you are exposed to high levels of carbon monoxide, see a doctor immediately. Do not drive if you are experiencing symptoms (get someone else to drive or call for an ambulance).

Figure 7.10. Tailpipe-exhaust extraction systems use fans and ducts to capture vehicle exhaust.

Figure 7.11. Tailpipe-exhaust extraction systems must be vented outdoors, away from building air intakes.

Figure 7.12. Do not burn charcoal in buildings, tents, or campers. Burning fuels produce dangerous levels of carbon monoxide, as seen in the gas monitor display on the right. In this case, a small pile of burning charcoal briquettes was creating a carbon monoxide concentration of 433 parts per million (433 ppm). This is far above the "ceiling" concentration of 200 ppm, which the National Institute for Occupational Safety and Health (NIOSH) says should not be exceeded at any time.

Discussion

1. Consider the facts and case reports in the first part of this lesson.
   a. What are some reasons people may not realize they are being exposed to carbon monoxide?
   b. What do you believe are the most common situations when a person might be exposed to carbon monoxide at your workplace?
2. Consider the safety recommendations in the "Protect Yourself and Others" section of this lesson.
   a. Explain at least two safety recommendations that you already follow.
   b. Discuss any other safety recommendations you would like to take after studying this lesson. Are you confident that you have (or can get) the equipment and knowledge you need?

Quiz Yourself

1. Carbon monoxide is produced by engines fueled with gasoline, diesel fuel, or _____.
   a. electricity
   b. LP gas
2. Furnaces and space heaters should be vented _____ if they burn natural gas, wood, kerosene, propane, heating oil, or charcoal.
   a. indoors
   b. outdoors
3. If you must use a power washer indoors, use one that runs on _____ to prevent carbon monoxide poisoning.
   a. electricity
   b. gasoline
4. While running a tractor engine in a maintenance shop, prevent carbon monoxide poisoning by _____.
   a. closing all shop doors and windows
   b. attaching a fan-powered exhaust hose to the exhaust pipe
5. Install _____ detectors if fuel-burning equipment is used indoors.
   a. carbon monoxide
   b. oxygen

Lesson 8.
Welding Fumes and Gases

Welding, torch cutting, brazing, and soldering are considered hot-work activities. These operations can produce harmful fumes and gases. For instance:

- ***Brief, heavy exposure*** to thick fumes may irritate the eyes, nose, throat, and lungs. Dizziness, headache, and nausea may also occur. In unventilated confined spaces, gases from welding may displace normal air and cause suffocation.
- ***Long-term exposure*** to fumes and gases may cause permanent lung damage and increased susceptibility to lung infections, pneumonia, and cancer. Fumes from certain metals have also been linked to heart damage, stomach ulcers, kidney damage, and nervous system disorders.
- ***Hazards are greatest*** where ventilation is limited, especially indoors, in small rooms, and in confined spaces such as storage tanks.

This section discusses ventilation and other protections against fumes and gases in hot-work operations.

Figure 8.1. Welding, torch-cutting, and other hot work expose farmers to various fumes and gases. Some can be harmful, especially in poorly ventilated areas.

Severe Reactions to Fumes and Gases from Hot Work

Metal fume fever is common among welders and torch cutters, especially when heating galvanized metals and other materials containing zinc or copper. The flu-like symptoms of metal fume fever usually begin a few hours after exposure and end in one or two days. Typical effects include fever, headache, fatigue, muscle ache, and cough. Workers usually recover without treatment, but prompt medical attention helps prevent complications.

Chemical pneumonitis is an inflammation of the lungs caused by toxic chemicals. It is characterized by shortness of breath, coughing, fever, fluid in the lungs, and pink frothy sputum. Prompt medical attention is required. In welding, chemical pneumonitis may be caused by any of the following:

- Fumes from metals containing beryllium compounds, mercury, cadmium oxide, nickel, copper, and manganese.
- Irritating gases such as hydrogen fluoride, chlorine, and nitrogen dioxide.

Pulmonary fibrosis is a buildup of scar tissue in the lungs. Pulmonary fibrosis interferes with breathing. It can be caused by exposure to welding fumes.

Manganism is a serious nervous system disorder. It can develop over months or years of welding and cutting metals that contain manganese. The signs and symptoms are similar to Parkinson's disease and may include irritability, hallucinations, tremors, spasms, difficulty walking, and problems with memory and concentration.

Other illnesses have been linked to welding and hot work. Some of these are addressed by OSHA standards involving cadmium, hexavalent chromium, lead, and beryllium.

Case Reports

Here is a sample of cases that illustrate some common ways workers have been exposed to harmful fumes and gases during hot work.

Farmer develops metal fume fever while cutting with a torch. A healthy, nonsmoking 38-year-old farmer spent five hours cutting galvanized steel with a gas torch. He did not wear a respirator. Two hours after finishing, he developed a dry cough and trouble breathing. Soon, he felt cold, became shaky, and had severe cramps in his legs. These symptoms lasted about six hours. The next morning, he felt weak and was coughing up mucus. He saw a doctor and was diagnosed with metal fume fever. He recovered fully with no complications. Source: Heydon, J. L., & Kagan, A. N. (1990). Metal fume fever. *New Zealand Medical Journal, 103*(883), 52.

Chemical pneumonitis and fibrosis from cadmium and zinc fumes. A 26-year-old man was soldering brass. He used a solder with a high percentage of cadmium and zinc. After a few hours, he noticed tightness in his chest and soon developed a forceful, dry cough. He experienced chills, shortness of breath, and a choking sensation later that evening. The next day, he was coughing up small amounts of blood. A doctor prescribed antibiotics and a cough suppressant, but his condition did not improve. He went to the emergency room on the fourth day of illness. Doctors found fluid in his lungs. His lungs were also not fully expanding, and he had high levels of cadmium and zinc in his urine. He was diagnosed with acute pneumonitis caused by cadmium. The fluid in his lungs cleared up, but two years later, his lungs were still not expanding fully. Doctors believed the long-term effects were caused by scarring, or fibrosis, of the lungs. Source: Anthony, J. S., Zamel, N., & Aberman, A. (1978). Abnormalities in pulmonary function after brief exposure to toxic metal fumes. *Canadian Medical Association Journal, 119*(6), 586-588.

Worker asphyxiated by argon gas inside 200-gallon tank. A worker used argon as a shielding gas while welding inside a tank. With no ventilation, argon displaced oxygen in the tank, and the worker died of asphyxiation. Source: *OSHA Inspection 106812688*.

Protect Yourself and Others

Planning stage:

- Whenever possible, use welding methods and materials that generate fewer or less-harmful fumes and gases.

Preparation:

- Solvents, paint, and other residues may create toxic fumes or gases when heated. Remove them from metal surfaces before applying heat.
- Hazardous paint or coatings should be stripped back at least 4 inches from the point where the arc or flame contacts the metal. Observe all OSHA regulations if the metal is covered with asbestos or lead-based paint.
- Cleaning solvents may contain chlorinated compounds. These compounds may produce harmful phosgene gas when exposed to ultraviolet rays from welding. To prevent the release of gas, make sure cleaned surfaces are thoroughly dry and keep solvent containers away from light emitted by welding. Chlorinated cleaning compounds include (but are not limited to) carbon tetrachloride (CT), 1,1,1-trichloroethane (TCA), and perchloroethylene or tetrachloroethylene (PERC, PCE, TCE).

Ventilation:

- Ensure adequate ventilation and position yourself to avoid breathing contaminants. Consider the following issues:
  - **Natural ventilation** refers to the movement of air through a workplace without the use of fans. Natural ventilation occurs through open windows, doors, and vents or from natural breezes when working outdoors. Natural ventilation may be suitable for large, open areas with low-toxicity contaminants.
  - **General mechanical ventilation** is provided by exhaust fans mounted on a building's walls or roof. Makeup air must be supplied through vents, open windows, or doors. When designed to move welding fumes away from workers, general mechanical ventilation offers more protection than

natural ventilation alone. However, because it merely dilutes contaminants and disperses them more broadly through the workspace, it may not be appropriate for highly toxic substances.

— **Local forced ventilation** refers to the practice of placing a fan next to a worker to blow air across the body.

— **Local exhaust ventilation** uses fume extractors and hoods (often called smoke eaters) to remove contaminants from a worker's breathing zone. These systems are highly effective when the nozzle or hood is positioned very close to the welding plume. Local exhaust systems may be designed to expel fumes outdoors, or they may be designed to remove contaminants from exhaust air and recirculate the cleaned exhaust indoors. Keep these points in mind:

- **Outdoor exhaust:** If there are ducts to send the fumes outdoors, be sure the building's fresh air intakes are open to supply makeup air and prevent toxic backdrafts through flues, drains, manure storage pits, etc. Also, be sure welding exhaust vents are located away from windows, doors, and fresh air intakes.
- **Indoor recirculation:** If the ventilation system is designed to clean and recirculate the air, keep in mind that the filters may not remove all harmful gases. This means natural or general mechanical ventilation is still necessary. Locate exhaust ports away from workers.

Figure 8.2. When possible, weld outdoors or in a well-ventilated area.

Figure 8.4. Local exhaust hoods remove welding fumes and help keep the workplace air clean.

Figure 8.3. Portable local exhaust systems, often called smoke eaters, capture fumes from welding and other hot-work activities.

Figure 8.5. This welding helmet has a built-in powered-air-purifying respirator (PAPR) to protect the worker from fumes.

- Ventilation is most effective when the worker's head is kept away from the work, and air blows sideways across the worker's body to create a cross draft.
- Note that for welding quality control, air velocity across the workpiece is usually limited to 100 feet per minute (0.5 meters per second). Higher airspeeds may disrupt the flame or arc, resulting in a poor weld.

Respiratory protection:

- Special respirators may be required if ventilation is inadequate. Refer to Table 1 in this section for details. Also, consult Lesson 12 of this document.

Confined spaces:

- Welding and other hot work are especially hazardous in confined spaces such as storage tanks, bins, vaults, and pits. Hot work inside these structures usually requires special ventilation and respirators, along with a permit-required confined space program. Refer to Table 1, Lesson 11, and Lesson 12.

Gas cylinders:

- Leaking gas cylinders can release toxic and flammable gases. Observe these precautions:
  - Store gas cylinders in well-ventilated areas.
  - Do not take oxygen or fuel gas cylinders into confined spaces such as silos, tanks, and pits.
  - Do not use leaking fittings or torches. Adjust, replace, or repair any leaking equipment immediately.

Other considerations:

- Keep nonessential coworkers away from welding, cutting, and other hot work. If this is not possible, ensure they are protected by adequate ventilation.
- If you smoke, ask your doctor about getting help to quit. Lung diseases are much more common in welders who smoke.
- If you experience irritation, dizziness, headache, nausea, or other symptoms of overexposure, move to fresh air immediately and seek medical attention.

Table 1. OSHA minimum ventilation and respirator requirements for welding, cutting, or heating certain metals.

Type of Metal	Working in Open Air (with no mechanical ventilation)	Working in Enclosed Spaces
Zinc-bearing base or filler metals or metals coated with zinc-bearing materials	Filter respirator	*Either* general mechanical ventilation *or* local exhaust ventilation may be used
Lead base metals	Filter respirator	*Either* general mechanical ventilation *or* local exhaust ventilation may be used
Cadmium-bearing filler materials	Filter respirator	*Either* general mechanical ventilation *or* local exhaust ventilation may be used
Chromium-bearing metals or metals coated with chromium-bearing materials	Filter respirator	*Either* general mechanical ventilation *or* local exhaust ventilation may be used
Metals containing lead (other than lead contained simply as an impurity) and metals coated with lead-bearing materials	Filter respirator	*Either* local exhaust ventilation *or* airline respirators may be used
Cadmium-bearing or cadmium-coated base metals	Filter respirator	*Either* local exhaust ventilation *or* airline respirators may be used
Metals coated with mercury-bearing metals	Filter respirator	*Either* local exhaust ventilation *or* airline respirators may be used
Stainless steel (when joined with inert-gas metal-arc welding)	—	*Either* local exhaust ventilation *or* airline respirators may be used
Beryllium-containing base or filler metals	Airline respirator	*A combination of both* local exhaust ventilation *and* airline respirators must be used

Table based on 29 CFR 1926.353.

Ventilation and respirator requirements apply to all workers exposed to welding fumes and gases in the immediate vicinity (and not just to the worker who is heating the metal).

See Lesson 12 for guidance on appropriate respirators and respiratory protection programs.

Discussion

1. Consider the facts and case reports in the first part of this lesson.
   a. What tasks expose you to fumes and gases from hot work at your job?
   b. Discuss any incidents or close calls involving hot work that you have heard about.
2. Consider the case report "Farmer Develops Metal Fume Fever While Torch-Cutting." Explain any two safety recommendations from the "Protect Yourself and Others" section that could have prevented the worker's illness.
3. Consider the case report "Chemical Pneumonitis and Fibrosis from Cadmium and Zinc Fumes." Explain two different safety recommendations in the "Protect Yourself and Others" section that could have prevented the illness. Use different recommendations than you reported for the previous question.
4. Consider the case report "Worker Asphyxiated by Argon Gas Inside 200 Gallon Tank." Explain two additional safety recommendations from the "Protect Yourself and Others" section that could have prevented the death. Use different recommendations than you have already reported.
5. Discuss any other safety recommendations you would give to less experienced workers.

Quiz Yourself

1. Gases from welding may displace normal air and cause suffocation in _____.
   a. storage tanks and other confined spaces
   b. pastures and other open areas
2. The symptoms of metal fume fever usually include _____.
   a. fever, headache, fatigue, muscle ache, and cough
   b. hair loss, brittle fingernails, and swelling of the hands
3. Solvents, paint, and other residues should be cleaned from metal surfaces to prevent the formation of _____ when heated.
   a. stray electric current
   b. toxic fumes and gases
4. Hazardous paint or coatings should be stripped back at least _____ from the point where the arc or flame contacts the metal.
   a. 2 inches
   b. 4 inches
5. Chlorinated cleaning solvents may produce harmful phosgene gas when exposed to _____ from welding.
   a. nitrogen
   b. ultraviolet light
6. To be effective, the nozzle of a fume extractor (smoke eater) must be kept _____.
   a. close to the welding plume
   b. above the welder's head
7. All types of ventilation are most effective when _____.
   a. the welder's head is kept away from the work
   b. ventilation air blows toward the worker's face
8. Store welding gas cylinders in _____.
   a. furnace rooms
   b. well-ventilated areas

Lesson 9.
Cleaning Products

Some cleaning products emit harmful vapors when improperly mixed or when used in poorly ventilated areas. Consider these facts about incompatible cleaners:

Bleach and ammonia release hazardous chloramine gas when mixed. Sodium hypochlorite is another name for bleach.

Bleach and acid cleaners produce harmful chlorine gas when combined. Acid cleaners include vinegar, many toilet cleaners, rust removers, and drain openers.

Acid and alkaline cleaners create dangerous acid vapors when poured in the same drain. Acid cleaners often contain sulfuric or hydrochloric acid. Alkaline cleaners include sodium hydroxide or potassium hydroxide.

Hydrogen peroxide reacts dangerously when mixed with many substances.

Figure 9.1. Cleaning products may react and emit hazardous vapors when mixed. Never mix cleaning products unless each product label says it is safe to do so.

Case Reports

The following cases illustrate common ways workers may be exposed to the hazards of cleaning products.

Worker hospitalized after mixing bleach and ammonia. A worker was cleaning inside a walk-in freezer with household bleach and ammonia. The mixture produced chloramine gas. She soon became short of breath and called 911. Her condition worsened despite aggressive treatment, and doctors had to install a breathing tube in her windpipe. Her lungs became severely inflamed, and she was placed on a ventilator with 100% oxygen. She gradually improved and was discharged from the hospital after seven days. Source: Tanen, D.A., Graeme, K.A., & Raschke, R. (1999). Severe lung injury after exposure to chloramine gas from household cleaners. *New England Journal of Medicine, 341*(11), 848.

Dairy worker hospitalized after mixing bleach and soap. At the end of a milking shift, a dairy worker poured soap into a bottle that had previously held bleach. This caused a chemical reaction. He was overcome by the vapors and had to be hospitalized. Source: *OSHA Inspection 119683803*.

Three dairy workers injured when hydrogen peroxide was mixed with acid. Three dairy workers suffered lung, eye, and mucus membrane irritation from vapors produced when peracetic acid was mixed with hydrogen peroxide. One of the workers was hospitalized. Source: *OSHA Inspection 1335937.015*.

Worker hospitalized after incompatible cleaners mixed in drain. A worker was unclogging a sink drain that contained bleach. He used a drain opener containing sulfuric acid. This caused a reaction that released chlorine gas. He was overcome and had to be hospitalized for a week. Source: *OSHA Inspection 301213013*.

Protect Yourself and Others

- Read and follow instructions on product labels.
- Never mix cleaning products unless each product label says it is safe.
- Never use gasoline as a cleaner. Gasoline is harmful to breathe. It is also harmful when absorbed through the skin, and it is highly flammable.
- Work in a well-ventilated area when mixing livestock foot baths. The products may contain formalin, formaldehyde, glutaraldehyde, copper sulfate, and other hazardous ingredients.

Figure 9.3. Never use gasoline as a cleaner. It is toxic and highly flammable.

Figure 9.2. Follow all label instructions when using cleaning chemicals.

Figure 9.4. Livestock foot baths may contain formaldehyde and other hazardous chemicals. Work in a well-ventilated area and follow label directions when mixing foot bath solutions. (Credit: Agricultural Research Service)

Discussion

1. Consider the facts and case reports in the first part of this lesson. What are some reasons people might not realize it can be hazardous to mix certain cleaning products?

2. Consider the safety recommendations in the "Protect Yourself and Others" section. Explain at least two of the safety recommendations that you will always try to follow.

Quiz Yourself

1. One of the following statements is true. The other is false. Which statement is true?
   a. Bleach and ammonia cleaners can be safely mixed.
   b. Bleach and acid cleaners can produce harmful gases when mixed.

2. One of the following statements is true. The other is false. Which statement is true?
   a. Hydrogen peroxide reacts dangerously when mixed with many substances.
   b. It is safe to use gasoline as a cleaning product around the farm

3. One of the following statements is true. The other is false. Which statement is true?
   a. Vinegar and bleach can be safely mixed.
   b. Acid and alkaline cleaners create dangerous vapors when poured into the same drain.

Lesson 10.
Farm Maintenance Chemicals

Farmers handle a variety of chemicals during maintenance tasks. Many are flammable, most are hazardous if swallowed, and many are absorbed through the skin and eyes. This section focuses on the hazards of breathing the vapors and gases these chemicals emit.

Fuels, degreasers, oil-based paints, thinners, and solvents emit vapors that can affect the nervous system. Too much exposure may cause headaches, dizziness, sleepiness, nausea, and confusion. Extreme exposure may cause cancer or damage to internal organs.

Chlorinators used in well-water systems release chlorine gas, which can harm our airways and lungs. Chlorine granules and tablets produce gas immediately upon contact with water. Bottled chlorine and distribution lines can emit gas from unexpected leaks during maintenance. Even household bleach emits chlorine gas when used in well-water systems.

Ammonia used in refrigeration systems can harm the airways and lungs if leaks occur when changing bottles or making repairs.

Lead-based paint produces harmful dust when scraped or sanded. If we breathe or swallow this dust, it causes damage to the brain, liver, kidneys, and circulatory system. Severe lead poisoning can even result in death. Residential paints made before 1978 may contain high levels of lead. Many industrial and special-use paints are still made with lead, including some paints used on machinery and manufactured buildings. Contact the machinery or building manufacturer before sanding, scraping, or welding the painted surfaces of farm machinery or manufactured buildings.

Case Reports

Here are some actual cases that illustrate how workers have been hurt by chemicals in maintenance activities.

Workers sickened by vapors from oil-based primer. A worker was priming and painting shelves under a return air intake in a storage room. The oil-based primer contained xylene, ethylbenzene, and other solvents. Vapors were drawn through the ventilation system and spread to other rooms on the same floor. Thirteen occupants of those rooms were overcome by vapors and had to be hospitalized. Source: *OSHA Inspection 115042145*.

Workers suffer lead poisoning while stripping paint. Seven workers used power tools to remove exterior paint from an old house. They did not take

Figure 10.1. To avoid adverse health effects, handle fuels in well-ventilated areas, away from sparks and flames. (Credit: Agricultural Research Service)

Figure 10.2. Lead-based paint can release harmful dust when scraped or sanded. (Credit: Agricultural Research Service)

steps to protect themselves from the lead dust they were creating. All seven suffered lead poisoning and had to be hospitalized. Source: *OSHA Inspection 300605995*.

Protect Yourself and Others

- Read all product labels and follow safety instructions.
- Use chemicals in well-ventilated areas. Take steps to keep vapors from spreading to other areas in the workplace.
- Switch to safer products when feasible. For instance, water-based solvents and coatings may emit less hazardous vapors compared to oil-based products.
- Keep water away from chlorine tablets and granules during storage and handling. If premixing is required, work outdoors away from building air intakes. If a well has to be shock chlorinated, contact your county extension agent for complete guidelines.
- Wear a full-face respirator with appropriate chemical cartridges when changing bottles or adjusting systems that use chlorine, ammonia, or other pressurized gases. See Lesson 12 for further details.
- Precautions for removing lead-based paints are beyond the scope of this document. See the websites of the Occupational Safety and Health Administration, the Environmental Protection Agency, or the Office of Housing and Urban Development for guidance.

Figure 10.3. Some paints and thinners emit potentially hazardous vapors. Read and follow all precautions listed on the label and safety data sheet (SDS).

Figure 10.4. Chlorine tablets and granules produce hazardous chlorine gas upon contact with water. Follow the manufacturer's instructions carefully.

Discussion

1. Consider the facts and case reports in the first part of this lesson.
2. When are you most likely to be exposed to gases and vapors from maintenance chemicals?
3. Describe any precautions you've already been following to reduce exposure during these tasks.
4. Consider the case report "Workers Sickened by Vapors from Oil-based Primer." Explain the safety recommendations in the "Protect Yourself and Others" section that could have prevented the workers' illnesses.
5. Discuss any other precautions you should take from the "Protect Yourself and Others" section of this lesson.

Quiz Yourself

1. Wear a/an _____ when changing bottles of chlorine for drinking well systems.
   a. N95 dust mask
   b. full-face respirator with chlorine cartridges
2. Chlorine granules and tablets produce large amounts of harmful chlorine gas upon contact with _____.
   a. plastic
   b. water
3. Vapors from fuels and solvents _____ affect the nervous system.
   a. can
   b. cannot
4. Lead-based paint produces _____ when sanded.
   a. toxic dust
   b. harmless dust
5. If chlorine water treatments must be premixed with water, work outdoors and keep away from _____.
   a. natural breezes
   b. building air intakes

Lesson 11.
Evaluating Confined Spaces

Certain areas on a farm are known as confined spaces. Examples include many types of silos, wells, cisterns, sumps, septic tanks, sewers, manholes, underground vaults, storage tanks, pits, and bins. If a confined space contains potential hazards, it may also be designated as a "permit-required confined space." Special precautions are required whenever a worker enters a permit-required confined space. The following steps explain how to evaluate a space and determine what precautions may be necessary.

Figure 11.1. A confined space is large enough to enter fully and work inside. The black storage tank of this water well is large enough to enter. Thus, it may be considered a confined space if it also has limited entry/exit and is not designed for continuous occupancy. In contrast, the light-colored pressure tank is not a confined space because it is too small to enter and work inside.

Figure 11.2. A confined space has limited means of entry and exit. To illustrate, this irrigation manhole can only be entered using the hatch and ladder. (Credit: USDA)

Confined Spaces

A "confined space" has all three of the following characteristics:

- ***A confined space is large enough for a person to enter and work inside.*** For instance, a 500-gallon tank may be a confined space if you can get your entire body inside. On the other hand, a 5-gallon bucket is not a confined space because it is too small to get fully inside and work.

Figure 11.3. A confined space is not designed to be continuously occupied by workers. For instance, this silo was designed for storing silage and not for accommodating workers on a routine basis. (Credit: Agricultural Research Service)

- ***A confined space also has limited means for entry and exit,*** such as a small entrance that requires crawling or climbing. To illustrate, an upright silo may be a confined space if you have to enter through a small hatch or climb a ladder once inside. A bathroom, however, does not usually qualify as a confined space because you can enter through a regular door.
- ***In addition, a confined space is not designed to be continuously occupied by workers.*** A manure pit may be a confined space because it is designed for storing manure and not for everyday occupancy by workers. On the other hand, a small office is not normally a confined space because it is designed to accommodate daily human activities.

If a space is large enough to enter and work inside, has limited entry and exit, and is not designed to be continuously occupied, it is considered a confined space. To identify precautions for entering a confined space, determine whether it is "permit required," as follows.

Permit-required Confined Spaces

Confined spaces require precautions only if they are permit-required confined spaces. A permit-required confined space is a confined space that has one or more of the following hazards:

- ***A material that could flow and engulf a worker.*** Examples of materials that flow include grains, liquids, fertilizer pellets, gravel, sand, sawdust, and similar bulk materials.
- ***Converging walls or a floor that slopes into a narrow opening*** where a worker could get stuck (such as a hopper or unloading chute).
- ***Other serious hazards,*** including, but not limited to:
  - Hazardous moving parts, such as augers and mixing blades.
  - Worker activities, such as welding, torch cutting, and the use of hazardous chemicals, that create hazards.
  - Exposed electrical parts with hazardous voltages.
- ***A potential for a hazardous atmosphere*** (bad air) due to any of the following:
  - Flammable gas, vapor, or mist above 10% of its lower flammable limit (LFL).
    - Examples include methane gas, fuel vapors, lubricant mist, carbon monoxide gas, hydrogen sulfide gas, etc.
  - Airborne combustible dust above its LFL (for instance, combustible dust thick enough to obscure vision at a distance of 5 feet).

Figure 11.4. A confined space may be permit-required if it contains a material that can flow and engulf a worker, such as grain or liquid.

Figure 11.5. A confined space may be permit-required if it has a funnel-shaped bottom where a worker could get stuck, such as these hopper-bottom bins. (Credit: USDA)

  - Some examples of combustible dust include grain dust, flour, sugar dust, and the dusts of many metals.

- Oxygen concentration below 19.5% or above 23.5% (oxygen-deficient or oxygen-enriched air).
  - Oxygen-deficient air often occurs inside tanks, vaults, pits, wells, and other enclosures where hazardous gases and vapors are found.
- Any airborne substance above the OSHA permissible exposure limit (PEL).
  - Examples include harmful levels of ammonia, chlorine, nitrogen dioxide (silo gas), hydrogen sulfide (sewer gas, well gas), carbon monoxide, and grain dust. The permissible exposure limit is a concentration that may be harmful if you are exposed for an entire workday, even though it may not cause instantaneous harm.
- Any airborne hazard that is considered "immediately dangerous to life and health" (IDLH).
  - These are the same substances listed above, but in even higher concentrations. The immediately dangerous to life and health concentration may cause permanent harm or an inability to escape from a hazardous area, even with a brief exposure.
- The only way to know if the air in a confined space is hazardous is to test it with special air monitoring instruments. If testing is not practical, assume hazardous air is present and take the necessary precautions.
- You can find information about lower flammable limits, permissible exposure limits, and immediately dangerous-to-life-and-health concentrations on the OSHA website. You can also find these in the online *NIOSH Pocket Guide to Chemical Hazards*.

OSHA's permit-required confined spaces standard usually applies if a space has all three characteristics of a confined space *and* one or more characteristics of a permit-required confined space.

Full requirements of the OSHA permit-required confined spaces standard (including exceptions) can be found on OSHA's website. A summary of these requirements follows. Note: For grain storage structures at elevators and milling operations, see OSHA's grain handling standard, which has similar, but not identical, requirements for entry.

Figure 11.6. A confined space may be permit-required if it has other serious hazards, such as this mechanical sweep auger.

Figure 11.7. A confined space may be permit-required if it has the potential for a hazardous atmosphere. Underground confined spaces often contain low oxygen concentrations or asphyxiating gases.

Protect Yourself and Others

- Use signs and barriers to prevent unauthorized entry.
- When entry is authorized, evaluate hazards before and during entry.
- Use entry permits that document the needed precautions.
- Test and monitor hazards. When testing air, test in the following order:
  - Oxygen
  - Combustible gases and vapors
  - Toxic gases and vapors
- Ventilate, if necessary.
- Use two-way communication equipment.
- Use appropriate personal protective equipment.
- Provide adequate lighting.
- Erect barriers around manholes and access points to keep out any new hazards while workers are inside.
- Use ladders or other equipment for safe entry/exit.
- Provide rescue and emergency equipment (or use an outside rescue service).
- Provide any other equipment necessary for safe entry and rescue.
- Provide at least one attendant outside the space.
- If one attendant monitors multiple spaces, make sure the attendant can respond to an emergency without being distracted from the other spaces.
- Designate and train workers who will have active roles (e.g., authorized entrants, attendants, and entry supervisors).
- Establish procedures for rescue and emergency services. Do not allow unauthorized personnel to attempt a rescue.
- When workers of different employers are on site, coordinate any entry activities with all employers.
- Establish procedures for concluding entry (e.g., closing the space and canceling the permit).
- Review the permit space program annually. Also, review/revise when problems occur.

Figure 11.9. Monitor the air before and during entry to permit-required confined spaces.

Figure 11.8. Use signs and barriers to keep unauthorized people out of permit-required confined spaces.

Figure 11.10. Ventilate, if necessary, to reduce airborne hazards.

Discussion

1. Consider the facts about confined spaces in the first part of this lesson.
   a. Describe some spaces at your workplace that may be considered confined spaces.
   b. Explain how these spaces meet the three requirements of a confined space.
2. Consider the facts about permit-required confined spaces in the first part of this lesson.
   a. Describe some spaces at your workplace that may be considered permit-required confined spaces.
   b. Explain the hazards that may be present in these spaces.
3. Describe any precautions your workplace uses to keep unauthorized people out of permit-required confined spaces.
4. Are workers allowed to enter permit-required confined spaces at your workplace? If so, describe any precautions that are taken.
5. Consider the recommendations in the "Protect Yourself and Others" section of this lesson. Describe any new precautions that might be needed at your workplace.

Figure 11.11. Use appropriate respirators if ventilation does not adequately control airborne hazards.

Figure 11.12. Provide outside attendants, rescue equipment, and trained rescuers in case of emergency.

Quiz Yourself

1. Which of the following is most likely to be considered a confined space according to OSHA regulations?
   a. 5-gallon bucket that is too small to enter and work.
   b. 500-gallon tank that is large enough to enter and work.
2. Which of the following is most likely to be considered a confined space according to OSHA regulations?
   a. manure pit that you enter through a small hatch.
   b. small office that you enter through a regular door.
3. Which of the following is most likely to be considered a confined space according to OSHA regulations?
   a. maintenance shop that you enter and exit through a regular doorway
   b. upright silo that you enter and exit using a ladder
4. Which of the following is most likely to be considered a permit-required confined space according to OSHA regulations?
   a. confined space with low oxygen
   b. confined space with no recognized hazards
5. Special training and equipment _____ required before entering a permit-required confined space.
   a. are
   b. are not

Lesson 12.
Respirators

Even after following the precautions in other lessons, you might still encounter hazardous dust, fumes, vapors, or gases. In some situations, respirators may help. This lesson covers the pros and cons of several types of respirators.

NIOSH-Approved Respirators

The National Institute for Occupational Safety and Health (NIOSH) approves respirators used in work environments. NIOSH-approved respirators have an approval number that begins with "TC-." Respirators are grouped into two broad categories: Air-purifying and air-supplying, as follows:

Air-purifying respirators use filters to remove contaminants from the air. They do not supply oxygen, so they are used only where oxygen levels are normal. They cannot be used if the air is immediately dangerous to life and health (IDLH). Examples include the following:

Figure 12.1. Filtering facepiece respirator. (Credit: OSHA)

- ***Filtering facepiece respirator***
  - **Characteristics:**
    - Disposable.
    - Facepiece made of filter material
    - Two head straps.
    - May have an exhalation valve.
  - **Uses:**
    - Protects against low concentrations of low-toxicity dust, mists, and fumes in well-ventilated areas, including:
    - Grain, feed, and hay dust.
    - Mists from spraying latex paint.
    - Low-toxicity welding fumes (flame-resistant models are available).
  - **Limitations:**
    - Does not provide oxygen.
    - Does not protect against hazardous gases or vapors.
    - Does not protect the eyes.
    - Must be replaced periodically to maintain effectiveness.
    - Face must be clean shaven.
    - Requires periodic fit testing (unless respirator use is voluntary).
    - Not suitable for persons with certain medical conditions.

- ***Half-face air-purifying respirator***
  - **Characteristics:**
    - Disposable and reusable models are available.
    - Facepiece is made of rubbery material.
    - Uses cartridges to filter air.
  - **Uses:**
    - With a P-100 filter cartridge, it offers equal or better protection for dust, mists, and fumes, compared with filtering facepieces.
    - Additional filter cartridges provide limited protection against certain vapors and gases.
  - **Limitations:**
    - Filter cartridges must be chosen for each air contaminant.
    - Filter cartridges must be replaced periodically.
    - Does not supply oxygen.
    - Does not protect the eyes.
    - Face must be clean shaven.
    - Requires periodic fit testing and seal checks.
    - Not suitable for persons with certain medical conditions.
- ***Full-face air-purifying respirator***
  - **Characteristics:**
    - Similar to the half-face air-purifying respirator; however, it protects the eyes and provides a better seal around the face.
  - **Uses:**
    - Same as a half-face air-purifying respirator but provides a higher level of protection.
  - **Limitations:**
    - Same as a half-face air-purifying respirator but does provide eye protection.

Figure 12.2. Half-face air-purifying respirator. (Credit: OSHA)

Figure 12.3. Full-face air-purifying respirator. (Credit: OSHA)

- ***Gas mask (canister respirator)***
  - **Characteristics:**
    - Similar to half-face and full-face air-purifying respirators; however, the filter canister is larger for greater filtering capacity.
  - **Uses:**
    - Full-face models with appropriate canisters protect against brief exposures to low concentrations of certain fumigants, such as phosphine gas.
    - Other uses are the same as half-face and full-face air-purifying respirators but with greater filtering capacity.
  - **Limitations:**
    - Same as half-face and full-face air-purifying respirators.
- ***Powered air-purifying respirator (PAPR)***
  - **Characteristics:**
    - Battery-powered fan draws air through a filter cartridge.
    - Available in tight-fitting and loose-fitting models.
    - Loose-fitting models may include a hood.
    - Some models are designed as welding helmets with filter lenses.
    - Loose-fitting models can be worn with beards.
    - Higher level of protection and fewer medical restrictions, compared with nonpowered air-purifying respirators.
  - **Uses:**
    - Same as half-face and full-face air-purifying respirators, but with a higher level of protection.
  - **Limitations:**
    - Same as half-face and full-face air-purifying respirators, but medical restrictions are less stringent. For loose-fitting models, beards are acceptable, and fit tests are not required.

Figure 12.4. Gas mask (left), with a closeup of the label for the canister, provides limited protection against phosphine, ammonia, chlorine, and particulates (right).

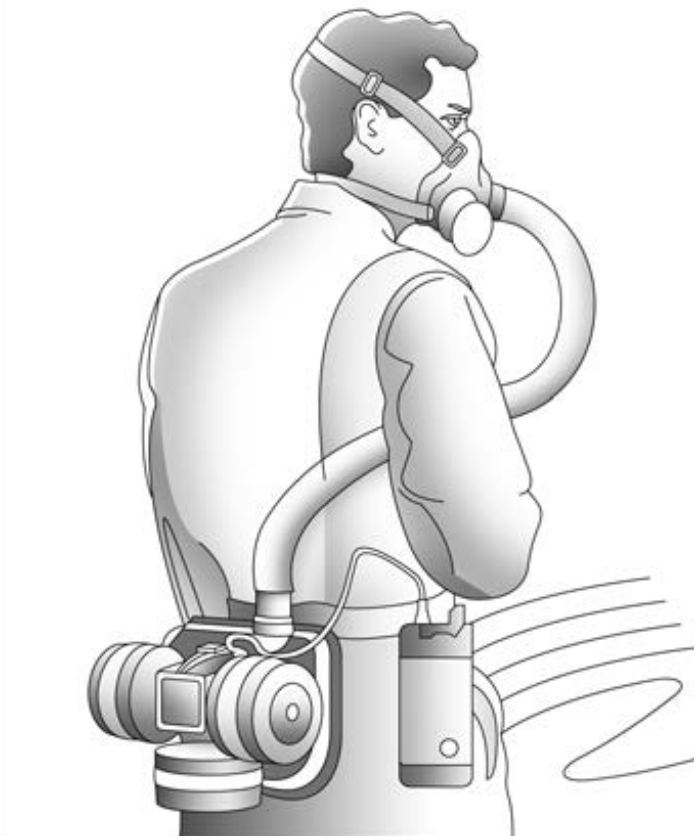

Figure 12.5. Half-face PAPR. (Credit: OSHA)

Figure 12.6. Full-face PAPR. (Credit: OSHA)

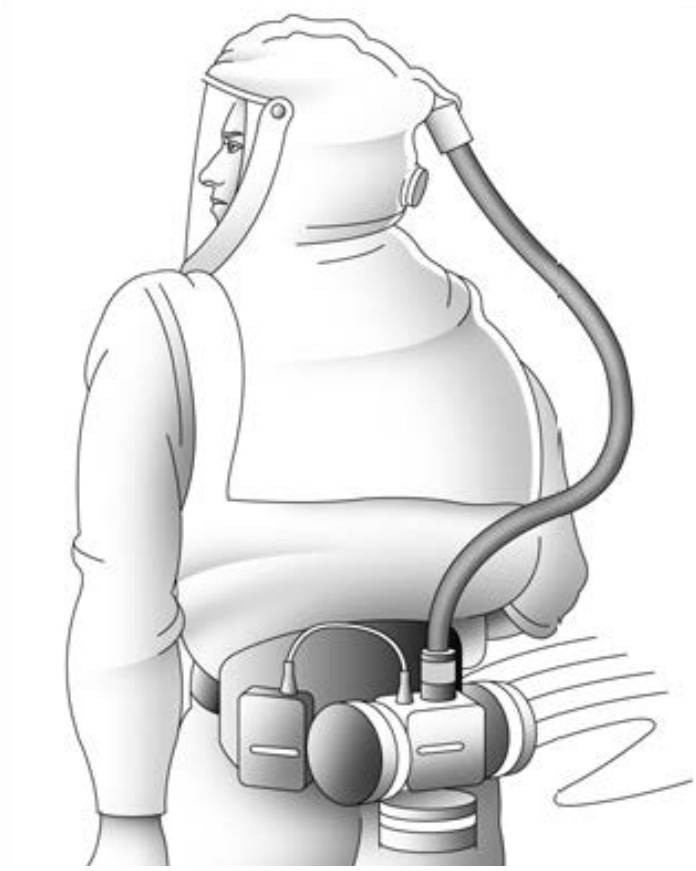

Figure 12.8. Hooded PAPR. Image: OSHA 3384 Hooded PAPR.

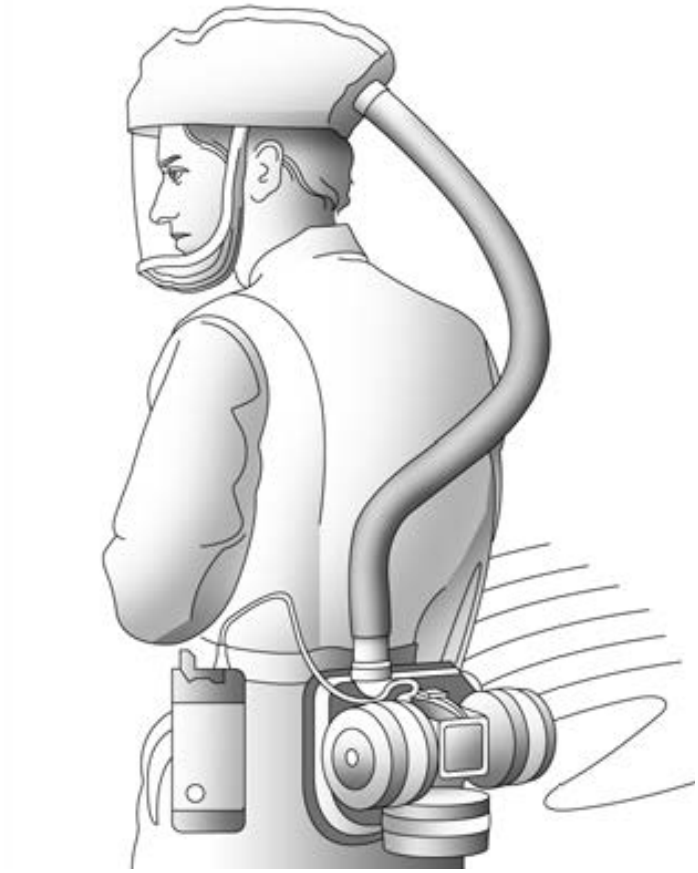

Figure 12.7. Loose-fitting PAPR. (Credit: OSHA)

N, R, and P numbers

NIOSH-approved particle filters and filtering facepieces include a letter and number to identify their filtering efficiency and oil resistance. Examples include N95, R99, P100. The letter refers to oil resistance: N means the filter is not resistant to aerosols containing oil, R means the filter has some resistance to oil, and P means the filter is very resistant to oil. The number refers to filtering efficiency: 100 means it filters at least 99.97% of airborne particles, 99 means it filters at least 99% of airborne particles, and 95 means it filters at least 95% of airborne particles.

Figure 12.9. Label of N95 filtering facepiece.

Figure 12.10. P100 filter cartridge.

Figure 12.11. Organic vapor cartridge.

Figure 12.12. Combination organic vapor/P100 cartridge.

Air-supplying respirators supply clean air from tanks or from special compressors located in clean environments. They do supply oxygen and can be used in environments with higher levels of toxic gases and vapors compared with air-purifying respirators. Examples include the following:

- ***Airline respirator***
  - **Characteristics:**
    - Supplies clean air through a long hose connected to a stationary cylinder or compressor.
    - Available with tight-fitting facepieces and loose-fitting hoods.
    - Loose-fitting models can be worn with beards.
    - Fewer medical restrictions and a higher level of protection compared with many air-purifying respirators.
  - **Uses:**
    - Permit-required confined spaces.
    - IDLH environments (in pressure-demand mode with auxiliary escape air supply).
  - **Limitations:**
    - Tight-fitting models require periodic fit testing.
    - For air-cylinder models, working time is limited by the amount of air in tanks.
    - Compressor models require a special compressor located in an environment free of air contaminants.

Figure 12.13. Airline respirator with auxiliary escape cylinder. (Credit: OSHA)

Figure 12.14. Self-contained breathing apparatus (SCBA). (Credit: OSHA)

- ***Self-contained breathing apparatus (SCBA)***
  - **Characteristics:**
    - Supplies clean air from cylinder worn on worker's body.
    - Tight-fitting facepiece.
    - Highest level of protection available.
  - **Uses:**
    - Permit-required confined spaces.
    - IDLH environments (in pressure-demand mode).
  - **Limitations:**
    - Requires periodic fit testing.
    - Working time is limited by the amount of air in the tank(s).

Case Report

Respirators and filters must be chosen according to the anticipated hazards. The wrong respirator will not protect you. Consider the following case of a worker who tried to use an air-purifying respirator when a supplied-air respirator was needed:

Agricultural worker dies using wrong respirator in confined space. A worker climbed into a 10,500-gallon molasses tank to reposition a drainpipe. The tank was about 12 feet wide and nearly 14 feet tall. The worker wore a full-face air-purifying respirator with ammonia cartridges. He entered the tank from the top opening, rappelled down, positioned the drain, and tried to climb back up. He was unable to get out and soon became unresponsive at the bottom of the tank. He was retrieved but pronounced dead at the hospital. Air monitoring in a similar molasses tank found low oxygen and high levels of poisonous hydrogen sulfide. *An air-purifying respirator with ammonia cartridges will not supply oxygen, does not protect against hydrogen sulfide, and is not approved for IDLH environments. Only a properly equipped airline respirator or SCBA can protect workers in IDLH conditions.* Source: Michigan State University Occupational and Environmental Medicine. (2016). *23-year-old laborer was overcome and drowned when he entered a 10,500-gallon molasses tank to reposition a drainpipe. MINIOSH FACE Report 16MI071*.

Respirator selection, maintenance, and use must be carefully planned according to your workplace respiratory protection program.

Respiratory Protection Program

If you need to wear a respirator, a written respiratory protection program offers guidance to ensure respirators are used safely and effectively. Here are some items that will be included in the program:

- Procedures for selecting appropriate respirators.
- Medical evaluations for workers who wear respirators.
- Procedures for using, cleaning, and maintaining respirators.
- Worker training.
- Fit testing.
- And many other considerations.

The complete requirements of OSHA's respiratory protection standard are beyond the scope of this document. For compliance guidelines and a fill-in-the-blank respiratory protection program, download the free *Small Entity Compliance Guide for the Respiratory Protection Standard* from the OSHA website.

Discussion

1. Consider the facts about respirators in the first part of this lesson.
   a. Describe any job tasks when you wear a respirator at work.
   b. What type(s) of respirator do you wear?
   c. Based on the information in this lesson, do you believe your respirator is a good choice for your work? Explain.
2. Consider the case report and facts about respiratory protection programs in this lesson.
   a. Explain how a respiratory protection program could have prevented the death in the case report.
   b. If you wear a respirator at work, describe what you know about your respirator protection program.
   c. If you wear a respirator at work, describe some important points you remember from your respirator training.
   d. Discuss any items that might need to be improved in your workplace respiratory protection program.

Quiz Yourself

1. Respirators approved by NIOSH have an approval number that begins with _____.
   a. TC-
   b. OSHA-

2. An N95 respirator protects against _____.
   a. dust from grain, feed, and hay
   b. gases like chlorine and ammonia

3. A full-face air purifying respirator with chemical cartridges _____ supply oxygen.
   a. does
   b. does not

4. A gas mask (canister respirator) with a phosphine canister protects against _____ of phosphine.
   a. brief exposures to low concentrations
   b. long exposures to high concentrations

5. Which air-purifying respirator is acceptable for someone with a facial beard?
   a. tight-fitting powered air-purifying respirator
   b. loose-fitting powered air-purifying respirator

6. Which respirator is acceptable for entering a well with low oxygen or high hydrogen sulfide levels?
   a. air purifying respirator
   b. airline respirator or self-contained breathing apparatus (SCBA)

7. Which respirator is acceptable for entering a manure pit with low oxygen or high hydrogen sulfide levels?
   a. air-purifying respirator
   b. self-contained breathing apparatus (SCBA)

8. If you need to wear a respirator at work, your employer will develop a written _____.
   a. HAZMAT response program
   b. respiratory protection program

9. If you need to wear a respirator at work, your employer will provide free _____.
   a. respirator training
   b. health insurance

10. If you need to wear a respirator at work, your employer will provide free _____.
    a. medical evaluations
    b. prescription medications

11. If you need to wear a respirator at work, your employer will provide free _____.
    a. employee assistance programs
    b. respirator fit testing

Lesson 13. Summary

To maintain good respiratory health on the farm, exposure to hazardous dust, gases, vapors, and fumes must be limited. The recommendations in this document can be summarized by these general safety principles:

Learn to recognize hazards.

- Grain and feed handling can release dust into the air. The hazard is greatest when grain and feed have spoiled and when workers are shoveling inside bins and other enclosures.
- Poorly ventilated structures may contain hazardous gases and low oxygen levels. Examples include storage tanks, wells, cisterns, manure pits, silage structures, and controlled-atmosphere (CA) storage rooms.
- Accidental exposure to anhydrous ammonia, pesticides, and other agricultural chemicals can be harmful.
- Deadly carbon monoxide is released from engines and heating appliances that burn fuel.
- Welding, cleaning, and maintenance activities can release toxic substances into the workplace air.

Figure 13.1. For livestock bedding, sand may emit fewer allergens than hay or straw.

Figure 13.2. Well-designed ventilation systems reduce airborne contaminants in livestock barns. (Credit: USDA)

Figure 13.3. Exhaust hoods (smoke eaters) reduce exposure to fumes and gases while welding.

Figure 13.4. Fuel-fired appliances should be vented outdoors.

Use less hazardous materials and equipment when feasible. For instance, electric machinery and appliances do not produce carbon monoxide and may be safer than fuel-fired equipment for dry indoor locations. In addition, welding materials and methods may be selected to produce less hazardous fumes.

Use ventilation to remove harmful dust, gases, vapors, and fumes. Well-designed ventilation systems keep work areas relatively free of manure gases, welding fumes, and exhaust from combustion appliances and engines.

Mechanize hazardous tasks when possible. For instance, mechanical unloading systems reduce the need for workers to enter bins and shovel grain.

Control moisture in grain, hay, and feed to limit microbial growth and reduce the toxicity of dust.

Install warning devices where hazards are expected. For example, install carbon monoxide alarms around fuel-fired equipment, and use oxygen monitors in controlled-atmosphere storage rooms.

Figure 13.5. Mechanical conveyors can reduce workers' exposure to agricultural dust.

Read and follow instructions on all farm equipment, machines, tools, heating appliances, and chemical labels.

Develop safety policies and procedures. Consider starting with the most hazardous tasks, such as those involving confined spaces.

If respirators and other personal protective equipment are needed, select them carefully and implement a written program governing their use.

Farm work can be hazardous, but methods exist to reduce the risks and help farmers lead healthier lives. For more information, contact the Occupational Safety and Health Administration, your farm association, or your county Extension agent.

Figure 13.6. Keep hay and grain in good condition by controlling moisture.

Figure 13.7. Install and maintain carbon monoxide detectors in buildings where fuel-fired machinery and appliances are used.

Discussion

1. List some changes you believe are important and attainable to improve safety at your workplace.
2. For each change you listed, make a plan that includes each of the following:
   a. Outline steps that will lead to the change you desire. Make sure each step is specific, measurable, attainable, and relevant. Set deadlines for each step.
   b. Identify potential barriers that might keep you from making the changes. Develop solutions for each potential barrier.
   c. Plan to keep a record of your behavior.
   d. Plan to seek support from advisors, coworkers, or others.
   e. Plan to be patient and celebrate small victories.

Answers to Quizzes

Lesson 2:

1. a
2. a
3. b
4. a
5. a
6. b
7. b

Lesson 3:

1. a
2. b
3. b
4. a
5. a
6. b
7. b
8. a

Lesson 4:

1. a
2. b
3. a
4. a
5. b
6. b
7. a

Lesson 5:

1. a

Lesson 6:

1. b
2. b
3. b
4. a
5. a

Lesson 7:

1. b
2. b
3. a
4. b
5. a

Lesson 8:

1. a
2. a
3. b
4. b
5. b
6. a
7. a
8. b

Lesson 9:

1. b
2. a
3. b

Lesson 10:

1. b
2. b
3. a
4. a
5. b

Lesson 11:

1. b
2. a
3. b
4. a
5. a

Lesson 12:

1. a
2. a
3. b
4. a
5. b
6. b
7. b
8. b
9. a
10. a
11. b

Workers' Rights

Workers have the right to:

- Working conditions that do not pose a risk of serious harm.
- Receive information and training (in a language and vocabulary the worker understands) about workplace hazards, methods to prevent them, and the OSHA standards that apply to their workplace.
- Review records of work-related injuries and illnesses.
- File a complaint asking OSHA to inspect their workplace if they believe there is a serious hazard or that their employer is not following OSHA's rules. OSHA will keep all identities confidential.
- Exercise their rights under the law without retaliation, including reporting an injury or raising health and safety concerns with their employer or OSHA. If a worker has been retaliated against for using their rights, they must file a complaint with OSHA as soon as possible, but no later than 30 days.

For additional information, see OSHA's Workers page (*osha.gov/workers*).

Whistleblower Protection

OSHA's Whistleblower Protection Program enforces protections for employees who suffer retaliation for engaging in protected activities under more than 20 federal laws.

The investigation of complaints of retaliation against employees is conducted by investigators in OSHA's regions. OSHA's investigators are neutral fact finders; they do not work for either the complainant or respondent (employer). For more information, visit the OSHA Whistleblower Protection Programs website (*whistleblowers.gov*).

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This material was produced under grant number SH-000179-SH4 from the Occupational Safety and Health Administration, U.S. Department of Labor. It does not necessarily reflect the views or policies of the U.S. Department of Labor, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.

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MF3708 June 2025