Module Four

Survey of Toxic Substances

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Survey of Toxic Substances

Time Allotted: 90 Minutes

Objectives:

Upon completion of this module, the learner will be able to

- Identify and understand the different types of outdoor pollutants and their toxic effects
- Understand the toxic effects of various types of metals, pesticides, and other chemicals
- Become familiar with ATSDR's ToxFAQs, Toxicological Profiles, and Fact Sheets

Presentation Outline

I. Introduction - Survey of Toxic Substances
   A. Outdoor Air Pollutants
   B. Chemicals of Concern

II. Heavy Metals

   A. Arsenic
   B. Cadmium
   C. Lead
   D. Mercury

III. Benzene

IV. Polychlorinated Biphenyls

V. Pesticides

   A. Insecticides
   B. Herbicides
   C. Fungicides
   D. Fumigants
   E. Rodenticides

VI. Radiation and Radioactive Materials

   A. Ionizing Radiation
   B. Non-ionizing Radiation

VII. Test Your Knowledge Quiz

VIII. Activity Lab

IX. Question and Answer Period

Lecture Notes

I. Introduction - Survey of Toxic Substances (1)

A. Outdoor Air Pollutants

☛ While this module deals with specific substances, this section has the flexibility to include or substitute other chemicals, depending on the interest and concern of the particular community. For that reason, this section should be presented by an environmental health professional (toxicologist, an environmental health scientist, a health educator). In addition, one or two toxic substances may be the focus of the module. This particular module will require additional research by the trainer.

EPA has focused its attention on the following outdoor pollutants, which may pose a health hazard from exposure (1): carbon monoxide, sulfur oxides, ozone, nitrogen oxides, and particulates. Other chemicals not listed, here, also have the potential to be toxic, however the focus is on the above listed chemicals because they are produced in the largest amount and/or have the greatest chance of producing a toxic effect.

Levels of air pollutants are different at different times of the day, and are usually highest around midday, decreasing in the evening. An accidental release of a chemical could also increase levels.

- Carbon Monoxide (CO) is a colorless, odorless, and tasteless gas produced by the burning of carbon or materials containing carbon. It is lighter than air and dissolves slightly in water. Some common sources of exposure to carbon monoxide include automobile exhaust and faulty or poorly ventilated charcoal, kerosene, or gas stoves. Foundries, coke ovens, and refineries are also sources, as are smoking tobacco products (2,11). Carbon monoxide decreases the amount of oxygen available to cells, resulting in problems with cell function.

Short term (acute) exposure to CO at certain levels could cause a slight headache and shortness of breath. Exposure for longer periods (chronic) may cause headache, nausea, irritability, increased respiration, chest pain, impaired judgement, and fainting.

- Sulfur oxides are a major source of air pollutants. They are produced from automobile exhaust, petroleum refineries, paper manufacturing, and chemical industries. The two types of sulfur oxides are sulfur dioxide (SO_2) and sulfur trioxide (SO_3). Sulfur dioxide is the main air pollutant of concern. It is an irritant colorless gas with a bitter taste, that dissolves in water to form sulfurous acid. It is a liquid under pressure and cannot catch fire. It affects the eyes and the skin as well as the upper respiratory system, and is able to penetrate the lungs during mouth breathing as opposed to nose breathing. Sulfur dioxide in the air results mainly from activities associated with burning of coal or oil, such as power plants or copper smelting (12). The people most often affected by exposure are workers in plants where sulfur dioxide occurs as a by-product, such as in the copper smelting industry (12). Sulfur dioxide in the body is biotransformed (changed) into a breakdown product which can be measured in blood and urine. That way, exposure can possibly be determined (12).

- Ozone (O_3) is a colorless gas and its odor can be detected at very low levels. It is formed as a result of the interaction between organic compounds, like ketones,

aldehydes, and unsaturated hydrocarbons, and nitrogen oxides in the presence of sunlight. It is also formed by any other high-energy source, such as lightning, high voltage electrical equipment, and air- and water-purifying devices (1).

Ozone is one of the major air pollutants in heavily industrialized areas and in cities with a large number of automobiles. More than half of the ingredients needed to produce ozone come from automobile exhaust. Ozone formation occurs most often during the early midday, and begins to decrease during late afternoon and evening.

Symptoms from exposure to low concentrations of ozone include eye, nose, throat, and lung irritation. These symptoms can be seen after only about 10 to 30 minutes of exposure. At higher concentrations, coughing and breathing problems occur. Even higher concentrations result in chest pain and pneumonia. People who suffer from lung diseases such as asthma and emphysema are more sensitive to lower levels of ozone.

- Nitrogen Oxides ($_{Nox}$) come in the following forms: nitric oxide (NO), which is a colorless gas; nitrogen dioxide (NO_2), a reddish-brown or dark orange gas; nitrogen trioxide (N_2O_3), a colorless gas; nitrogen tetroxide (N_2O_4), a colorless gas; nitrogen pentoxide (N_2O_5), and nitrous oxide (N_2O), which is colorless and often referred to as “laughing gas”(1,2)

Reports estimate that about 300,000 tons of NO_x are produced each year from industrial processes; combustion of fossil fuels (coal, oil) adds 10 million tons to that number (1). Nitrogen oxides are produced from many sources, such as burning of fuels in furnaces and internal combustion engines, detonation of explosives, welding, and tobacco smoke. Diesel exhaust may contain nitric oxide, while cigarette smoke also contains nitrogen oxides. The most common forms of nitrogen oxides in the air are nitric oxide and nitrogen dioxide. Nitrogen dioxide, which gives smog its brown color, can be detected by its odor or taste at low concentrations. Symptoms of exposure include coughing, difficulty in breathing, chest pain, fluid build-up in the lung, irregular heartbeat, and eye irritation (2).

In some people, only labored breathing and coughing may develop at first, and then the symptoms subside. A few weeks later, people may enter a second stage, characterized by fever, chills, and fluid in the lungs. Death may occur in either of the two stages, depending on the severity of the effects and the health of the individual.

- Particulates come from a number of sources, including automobile emissions, smokestacks, or blowing dust. The particles may be large enough to be seen by the naked eye, or they may be extremely small. The size is important in determining the effect of the particle on the respiratory system. Smaller particles may pose the greatest threat. For example, asbestos fibers are capable of causing cancer, silica

particles may cause a disease called silicosis, and coal dust may cause pneumoconiosis. The composition of the particulates is also important. Heavy metals, such as lead, cadmium, and others are often found in the particulate material (1).

II. Heavy Metals

Heavy metals are everywhere in nature as components of the earth's crust. Plants can absorb and accumulate metals, which may be toxic. Industrial development has resulted in exposure to heavy metals in people because of increased production of by-products such as cadmium, mercury, chromium, and zinc.

☛ Due to both the prevalence, relative toxicity, and the disproportionate exposure impact on poor and underserved communities, this module will describe the relative toxicity and health impacts from four of the most toxic heavy metals: arsenic, cadmium, lead, and mercury.

- Arsenic, one of the most toxic metals, is produced at a rate of about 60,000 tons per year. It is found primarily in a trivalent form or a pentavalent form (2). The pentavalent form is not as toxic as the trivalent form, and will not be discussed further here. The trivalent form of arsenic is the most toxic and it is deposited primarily in the respiratory tract. Excretion is primarily via the urine, although excretion may also occur by the natural shedding of the skin and through sweat.

  Potable water usually has a very small arsenic concentration. It is also present in very small amounts in such things as wine and seafood. This is why the diet

should be taken into account when determining arsenic exposure. The primary routes of exposure to arsenic are ingestion and inhalation. Arsenic tends to collect in skin, hair, and nails. It is removed mainly through the urine, a few days after it is ingested. This can result in some upset stomach. Measuring arsenic in the urine is the main way to detect arsenic exposure.

Acute exposure to arsenic may result in death, fever, anorexia, and liver enlargement (2). Chronic exposure may result in poisoning of the nervous system, liver damage, and peripheral vascular disease, which could result in gangrene of the lower limbs. This condition is more commonly known as "black foot disease" and was a phenomenon that occurred in Taiwan from arsenic contamination of the drinking water supply. In addition, skin cancer and lung cancer may result from chronic arsenic exposure. Chronic arsenic exposure has also been associated with leukemia, kidney, and bladder cancers, dermatitis, hyper pigmentation, and keratosis (or arsenical keratosis).

Approximately 900,000 workers in the United States may be occupationally exposed to arsenic fumes and dust such as in smelting industries. The major source of occupational exposures to arsenic in the United States is in industries involved in the manufacture of pesticides, herbicides, and other agricultural products.

- Cadmium is a byproduct of the mining and smelting of lead and zinc.(2). It does not corrode and is primarily used for electroplating activities. Cadmium can gather and concentrate in plants. It has also contaminated irrigation waters and is found in fertilizers. Shellfish represent a major source of cadmium in the diet (100-1,000 microgram per kilogram [µg/kg]). Cadmium is also found in tobacco, each cigarette has approximately 1-2 µg of cadmium. Approximately 1 µg of cadmium may be found in one liter of breast milk. Very little cadmium is absorbed through the ingestion route, and it is not easily absorbed.

  Acute toxicity from cadmium exposure occurs primarily through ingestion of contaminated beverages or food. This could result in nausea, vomiting, and abdominal pain. Acute toxicity through inhalation may result in chemical pneumonia and fluid in the lung. Irritation of the nose and throat, coughing, dizziness, weakness, chills, fever, chest pains, and labored breathing are also symptoms. Acute cadmium toxicity through inhalation may result in a condition known as metal fume fever. Chronic toxicity may result in chronic obstructive pulmonary disease, emphysema, and kidney disease. It may also result in adverse affects to the cardiovascular system and the skeleton (1,2).

- Lead is primarily used in the manufacture of batteries, plastics, china, ceramic glass, and paint products. It is the most widespread toxic metal on earth and is the second most hazardous substance found at sites listed on the National Priorities

List (NPL). Scientific evidence links exposure to lead and adverse health effects due to acute and chronic exposure to lead.

The primary route of lead exposure is ingestion. This could occur through eating lead-based paint flakes and chips (e.g., pica-like behavior), breathing contaminated dust, drinking contaminated water, and absorbing lead from lead-contaminated glaze in pottery. Children are particularly at risk. Approximately 35% of U.S. black children have blood lead levels greater than 10 μg/L (13). Blood lead levels are consistently higher for poor and minority children and for residents of largely urban areas. The fetal brain may be particularly sensitive to the toxic effects of lead because of the immaturity of the blood-brain barrier in the fetus.

The toxic effects of lead include lead encephalopathy (brain disease) in children, resulting in lethargy, vomiting, irritability, loss of appetite, and dizziness (1,2). In adults, lead causes high blood pressure, and adverse reproductive effects (lowered sperm count and sperm motility). One classic symptom of lead toxicity are the Burton's lines, which are purple-blue discolorations of the gums (1,2). The primary measure for treating lead toxicity is through chelation therapy (binding of lead with other metals to remove it from the body).

- Mercury is the third most toxic substance in the environment (1,2). Approximately half of all mercury is used to produce vapor lamps, fluorescent tubes, thermometers, and electrical products. It exists in a number of forms, which may affect different parts of the body. Organic mercury primarily affects the brain. Methyl mercury is the most toxicological form of the element and, by its accumulation in the central nervous system (CNS), may result in neurotoxic effects in adults and toxicity in the fetuses of mothers exposed to methyl mercury during pregnancy. Metallic mercury is slowly absorbed by the gastrointestinal system and is not as toxic as methyl mercury (14). Inorganic mercury (mercury salts) primarily affects the kidneys. Exposure to mercuric salts may lead to abdominal cramps and bloody diarrhea.

  Chronic mercury exposure may lead to tremor and personality disturbances and permanent CNS damage may result from methyl mercury exposure. Acute mercury exposure can be assessed by measuring the level of mercury in blood. Chronic exposure is best assessed by measuring the amount of mercury in urine (1,2). Chelation therapy is typically used in acute mercury poisoning.

☛ A classic epidemiological study of mercury exposure involves the occurrence of Minamata disease. Minamata disease results from methyl mercury poisoning and leads to a neurological disorder. Methyl mercury bioaccumulates in fish and shellfish. Thus, exposure to humans primarily occurred through consumption of methyl mercury-contaminated shellfish and fish from Minamata Bay.

III. Benzene

Benzene is a component and a by-product of gasoline. Benzene is widespread in the environment, and is one of the most prevalent solvents. In addition, it has been used as a solvent

in rubber, inks, adhesives, and transformer fluids (1,2). Benzene dissolves easily in the bloodstream and quickly diffuses from the lungs to the blood and is metabolized in the liver to compounds that interact with cellular DNA. In addition, it is lipid-soluble and is easily absorbed by the skin and by cells lining the digestive tract.

Inhalation is the predominant route of exposure to the toxic effects of benzene, particularly in the workplace. Acute exposure to benzene may result in CNS effects, which may lead to unconsciousness and death. There is no antidote for acute benzene poisoning. Chronic benzene exposure may result in bone marrow damage, resulting in anemia. Symptoms of chronic benzene exposure may include fatigue and anorexia. Leukemia is a classic outcome from chronic low-level exposure to benzene with a latency period of about 15 years.

IV. Polychlorinated Biphenyls (PCBs)

PCBs are another major contaminant of concern in communities (13). They were used in plasticizers, adhesives, and as dielectric fluids in capacitors. In humans, they accumulate in fat tissue and milk, which is a major route of excretion (1,2). PCBs cause liver cancer in rats and mice and is classified as a probable carcinogen in humans by EPA. PCBs are persistent in the environment and bioaccumulate upward in the food chain. A non-occupational source of PCBs is in fish from contaminated water. Cultures where subsistence fishing is a primary source of food would subsequently represent populations of concern regarding PCB-contaminated fish (15).

High-level exposure to PCBs may cause a classic dermatological condition called chloracne. Developmental and fetotoxic effects may also be observed in humans. Occupational exposures to PCBs primarily occurs in the production of electrical equipment. Since 1977, PCBs have been banned from further production as a material for the production of electrical equipment and chronic workplace exposure is now uncommon.

- Pesticides

Several classes of pesticides cause adverse human health effects in humans. These major classes of pesticides include insecticides, herbicides, fungicides, fumigants, and rodenticides. Seasonal agricultural workers have an increased risk of harmful human health effects due to pesticide exposure (16).

- Insecticides include the organochlorides, organophosphates, and the carbamates. Organochloride insecticides affect the peripheral nervous system (PNS) through dermal absorption, inhalation, and ingestion. Organochloride compounds also decrease antibody production, placing a person at risk for infection (1,2). DDT is a organochloride insecticide that persists and bioaccumulates in the environment, which is why it is no longer manufactured as a pesticide. Organophosphorous exposure may result in headache, anxiety, chest tightness, seizures, loss of consciousness, abnormal heart beat, and liver dysfunction (1,2). In addition, Organophosphorous pesticides, like malathion, seem to enhance the immune

response in some circumstances. Parathion has been known to decrease antibody production.

☛ Trainers may want to discuss the use of insecticides. Ask participants about their insecticide use, listing types and determining their knowledge of the contents of these substances.

- Herbicides such as 2,4,5-T, 2,4,-D, and the classic contaminant, 2,3,7,8 - TCDD (dioxin) are toxic to both animals and humans (1,4). Liver problems and nerve damage may result from chronic herbicide exposure, while chloracne is a classic symptom of herbicide dermal exposure.

- Fungicides are used in the treatment of fruit trees and vegetables and have a relatively low toxicity (2). Skin irritation, headache, nausea, vomiting, lethargy, and dermatitis are classic symptoms of some fungicides, such as creosote and hexachlorobenzene.

- Fumigants are used to eradicate insects, bacteria, and rodents. Fumigants are typically used on fruits, vegetables, ships, and buildings (1). Methyl bromide is a classic fumigant that may result in dermatitis, pulmonary irritation, headache, nausea, vomiting, dizziness, and dementia from exposure via inhalation and dermal exposure.

☛ The trainer may want to discuss the use of fungicides and fumigants in the home (home gardens, etc.).

- Rodenticides are used primarily to eradicate rats, mice, rabbits, and gophers (1,2). Warfarin is a rodenticide that causes severe adverse health effects.

☛ Participants may list the types of chemicals they use in the removal of pests. Determine through discussion, whether any adverse health effects have been seen.

VI. Radiation and Radioactive Materials

The two major classes of radiation are ionizing radiation and non-ionizing radiation. Ionizing radiation affects the bone marrow, resulting in a decrease in red blood cell production, reddening of the skin, gastrointestinal and reproductive effects, cataracts, birth defects, and respiratory illness (1,2). Non-ionizing radiation is associated with mutagenic and carcinogenic effects, primarily by UV radiation, which can alter the repair mechanisms for DNA and potentially lead to skin cancer.

The exposure of radium dial workers in the United States is the most classic epidemiological case of occupational radiation exposure. Ingestion of radium may result in bone cancer. Atom bomb survivors were also the victims of radiation exposure, as well as underground miners exposed to radon, patients irradiated with x-rays for ankylosing spondylitis, and children irradiated with x-rays for ringworm (1,2). In addition, radiation is associated with skin, thyroid, and lung cancers, particularly among uranium mine workers.

VII. Test Your Knowledge Quiz

1. What are some effects from arsenic exposure?

2. What form of mercury is the most toxic?

3. List some solvents you may use in the home.

4. List the different classes of pesticides.

5. How does carbon monoxide affect the body?

6. What are some sources of ozone?

7. List the different outdoor air pollutants discussed in the Module.

VIII. Activity Lab

Give the participants ATSDR ToxFAQs sheets, fact sheets, and copies of some Toxicological Profiles. Have them identify substances of interest, and use the reference materials to gather information on those substances. This module is also recommended for use with Module Three - Risk Assessment, as this activity lab could be used in conjunction with the components of the Risk Assessment activity lab.

IX. Question and Answer Period

HANDOUTS and VISUAL AIDS

MODULE IV

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ANSWERS FOR “TEST YOUR KNOWLEDGE” QUIZZES

MODULE ONE - TEST YOUR KNOWLEDGE QUIZ - ANSWERS

1. Which of these groups is usually designated as one of the most sensitive sub-populations for exposures to toxic substances?

   a. Adult women
   b. Infants
   c. Adult men
   d. Adolescents

2. You have worked at a chemical facility for 10 years. The facility does not require protective equipment, and you have developed a number of serious health effects in the last 7 years. You are possibly experiencing what type of exposure?

   a. Chronic
   b. Acute

3. You are worried about contamination of vegetables grown in contaminated soils. What type of toxicologist would you contact?

   a. Descriptive
   c. Regulatory
   b. Environmental
   d. Food

4. You are concerned about the risks associated with growing vegetables in soil with naturally high lead and arsenic concentrations. You are speaking of what type of substance?

   a. Toxin
   b. Toxicant

5. The larger the amount of exposure and the greater the dose, the greater the observed response, or effect.

   a. True
   b. False

6. What type of toxicologist takes samples of blood, urine or hair for testing?

   a. Descriptive
   c. Mechanistic
   b. Analytical
   d. Forensic

7. Toxic agents can be classified in terms of their physical state, their effects, and their source.

   a. True
   b. False

8. Which agency deals with the health effects that may occur from environmental exposure to toxic chemicals?

a. The Environmental Protection Agency
b. The Centers for Disease Control and Prevention
c. The Agency for Toxic Substances and Disease Registry
d. The Nuclear Regulatory Commission

9. Which database has information on emergency handling procedures, environmental data, regulatory status and human exposure?

a. TOXNET
b. HazDat
c. IRIS
d. MEDTREC

10. HazDat contains information on hazardous substances found at NPL and non-NPL waste sites, and on emergency events.

a. True b. False

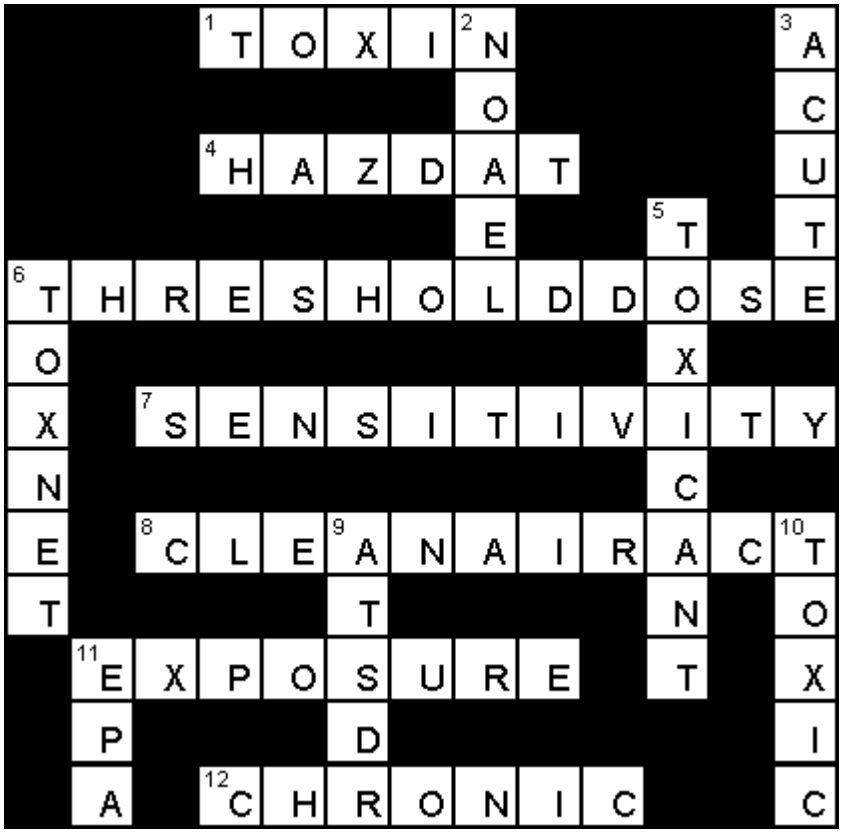
11. The no observed adverse effect level (NOAEL) is also known as the no effect level (NEL).

a. True b. False

12. The term *toxicant* is used when talking about toxic substances that are produced by or are a by-product of human-made activities.

a. True b. False

Module One - Toxicology Puzzle Solution



Module II - Routes of Exposure Word Scramble and Matching Solution

Word Scramble

(1)	**skin**	
(2)	**intestine**	_____
(3)	**nose**	_____
(4)	**eye**	_____
(5)	**mouth**	_____
(6)	**ambient**	_____
(7)	**macrophages**	_____
(8)	**environment**	_____
(9)	**biological**	_____
(10)	**gaseous**	_____
(11)	**soil**	_____
(12)	**air**	_____
(13)	**water**	_____
(14)	**food**	_____
(15)	**dermis**	_____
(16)	**inhalation**	_____
(17)	**route**	_____
(18)	**media**	_____
(19)	**groundwater**	_____
(20)	**food chain**	_____

QUICK MATCHING

Match the routes of exposure with the correct way for the hazard to enter the body.

A. Absorption
B. Ingestion
C. Inhalation

_A_ Skin
_B_ Mouth
_A_ Eye
_B_ Intestine
_C_ Nose

Module III - Risk Assessment Test Your Knowledge Quiz Answers

1. Which of the following is **NOT** a step in the Risk Assessment Process?
   a. Hazard identification
   b. Hazard evaluation or dose-response assessment
   c. Exposure dose
   d. Risk characterization

b. Epidemiology is the study of causative factors associated with the occurrence and number of cases of disease and illness in a specific population.

a. True b. False

c. Exposure tells the toxicologist what dose causes a "response" usually illness or death, in the test animal.

a. True **b. False**

d. What activities should be conducted during the hazard identification step of the risk assessment?
   a. Identifying the substance name
   b. Describing the physical/chemical properties of the toxic substances
   c. Identifying the sources of toxicity information
   d. Identifying the exposure pathway
   e. All of the above

5. Prospective epidemiological studies gather information from the past.

a. True **b. False**

6. The exposure assessment step in the risk assessment process identifies all **EXCEPT** which of the following?

   b. Frequency of exposure
   b. Type of chemical exposure
   c. Length of time of exposure
   d. Route of exposure
   e. Calculation of the amount of exposure

7. Susceptible populations that may be more at risk for illness than others includes the following **EXCEPT**:

   a. Young children
   b. Older adults
   c. Teenagers
   d. Women of Childbearing Age

Module IV - Survey of Toxic Substances Test Your Knowledge Quiz Answers

1. What are some effects from arsenic exposure?

   Death, fever, anorexia, and liver enlargement are some of the effects listed in the module.

2. What form of mercury is the most toxic?

   Methyl mercury is the most toxic form of mercury.

3. List some solvents you may use in the home.

   Participant answers

4. List the different classes of pesticides.

   Insecticides, Herbicides, Fungicides, Fumigants, Rodenticides

5. How does carbon monoxide affect the body?

   Decreases amount of oxygen available to the body. Also causes headache, shortness of breath, nausea, irritability, increased respiration, chest pain, impaired judgement, and fainting.

6. What are some sources of ozone?

   Lightning, high voltage electrical equipment, and air- and water-purifying devices are some sources of ozone.

7. List the different outdoor air pollutants discussed in the Module.
   Carbon monoxide, Sulfur oxides, Ozone, Nitrogen oxides, Particulates