Chemicals, the Environment, and You: Explorations in Science and Human Health

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Lesson 1
Engage

Chemicals, Chemicals, Everywhere

At a Glance

Overview
Students divide substances into categories: made of chemicals / not made of chemicals, synthetic / naturally occurring, and toxic / nontoxic. When the teacher reveals that all the substances are made of chemicals, students discuss how their concept of what a chemical is might differ from the scientific definition. Students observe a mystery chemical and determine what precautions they might need to take when handling an unknown substance. Then, students read case studies of real exposures to chemicals.

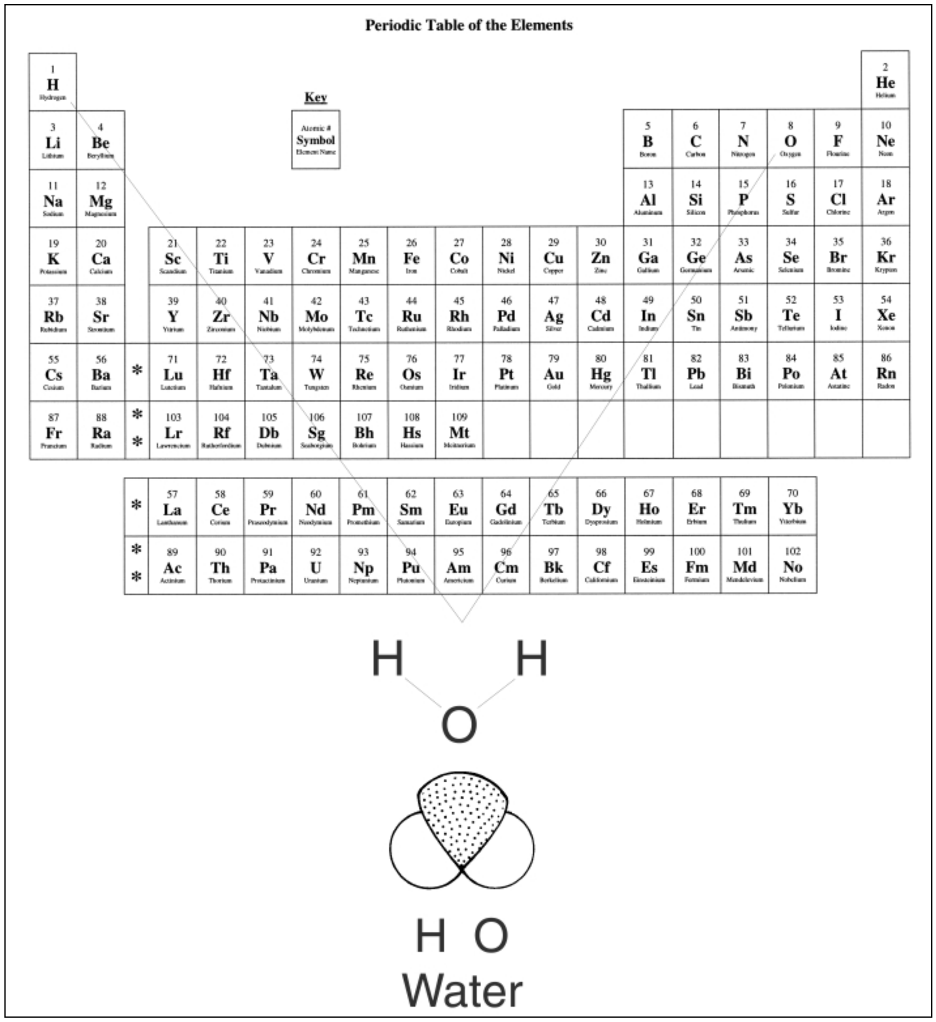
Major Concepts
Everything in the environment is made of chemicals. Both naturally occurring and synthetic substances are chemical in nature. People are exposed to chemicals by eating or swallowing them, breathing them, or absorbing them through the skin or mucosa, and they can protect themselves from harmful chemicals by blocking these routes of exposure.

Objectives
After completing this lesson, students will

- understand that everything in their environment is made of chemicals;
- indicate that both naturally occurring and synthetic substances are chemical in nature;
- recognize that their view of a chemical as "bad" or "good" relates to their perception of a chemical's potential toxicity to humans or other living organisms;
- realize that toxicologists study chemicals to find out if they are harmful to living organisms;
- understand that people are exposed to chemicals by eating or swallowing them, breathing them, or absorbing them through the skin or mucosa; and
- demonstrate that people can protect themselves from harmful chemicals by blocking these routes of exposure.

Background Information

What Is a Chemical?
Simply stated, **a chemical is any substance that has a defined molecular composition**. Molecules, which are the smallest units into which a compound can be divided and still be that compound, can be made up of one or more elements. Sometimes, the elements are the same, such as in oxygen: Two oxygen atoms are chemically bonded together to form the gas, oxygen, or O_2. Sometimes, the elements that form molecules are of different types, such as those in water: Two hydrogen atoms combine with one oxygen atom to form a molecule of water, or H_2O. All forms of matter are made of one or more of the more than 100 elements combined in many different molecular combinations. This means that all forms of matter are made of chemicals.



The Science of Toxicology

Long ago, humans observed that some chemicals derived from nature were poisonous. Poisonous chemicals produced naturally by living organisms (such as plants, animals, and fungi) are called **toxins**. Historically, knowledge of toxins was a powerful tool to use against enemies: many murderers in ancient Greece and later throughout Europe used toxins.[1] A significant contribution to the field of toxicology was made by the scientist Paracelsus (1493–1541). He recognized that the same chemical could have both therapeutic (medicinal) and toxic (poisonous) properties depending on how much of it was used. His work paved the way for the concept of the dose-response relationship (see Lesson 3 for more information about dose and response).[1]

Paracelsus

With the onset of the industrial revolution and the emergence of the science of synthetic chemistry, a variety of new chemicals was made by humans. It is estimated that more than 65,000 chemicals have been manufactured for commercial use in industrialized countries.[1] Whether on purpose or not, humans come into contact with these chemicals during manufacture, handling, or consumption. Exposure to a vast array of synthetic chemicals can occur when a person ingests food or drink, works in an agricultural setting with pesticides, or lives in a home among solvents, paints, plastics, and fuels. Although many of the chemicals greatly benefit us, some can have a toxic effect on human systems. These substances are called **toxicants**, a broad category that includes naturally occurring toxins.

How do people know if a chemical is toxic? The science of **toxicology** informs them of the nature of poisons. A **toxicologist** is a scientist who is trained to study the harmful effects of chemicals on living organisms. These harmful effects can include death, but not all toxicants are lethal. Some other harmful effects that toxicologists study are disease, tissue damage, genetic alterations, and cancer. Because there are so many ways that toxicants can affect living things and there are so many different kinds of chemicals in the environment, toxicology is a very broad science and there are many different kinds of toxicologists.[2]

What Do Toxicologists Do?

Descriptive toxicologists evaluate the toxicity of drugs, food additives, and other products. They ask the question, What happens if…? about the amount of a toxicant and the response that a living system has to the toxicant. The descriptive toxicologist might work in a pharmaceutical laboratory or in an academic setting doing data analysis, animal testing, and/or human clinical trials.[3]


Photo: Corel

Mechanistic toxicologists study how a chemical causes toxic effects on living organisms. They study biomedical research, biochemistry, and physiology to understand how a chemical is absorbed, distributed, and excreted. A mechanistic toxicologist uses information about how a chemical harms an organism in order to develop antidotes. This kind of toxicological work often is done in an academic setting or in private industry.[3]

Clinical toxicologists usually are physicians interested in the prevention, diagnosis, and treatment of poisoning cases. Clinical toxicologists specialize in toxicology issues concerning drugs used for treatment, such as side effects and overdoses; drugs of abuse, such as alcohol and cocaine; and accidental poisonings. These toxicologists have specialized training in emergency medicine and poison management. Veterinarians also can be clinical toxicologists who study poisons in animals.[3]


Photo: Cameron Davidson

Forensic toxicologists study the application of toxicology to the law. They work with pathologists and law enforcement officers at a crime scene. The forensic toxicologist uses chemical analysis to help establish the cause of death and determine the circumstances of death in a postmortem investigation.[2]

Environmental toxicologists study the effects of pollutants on organisms, populations, ecosystems, and the biosphere. Toxicologists concerned with the effects of environmental pollutants on human health fit into this group. Most commonly, however, environmental toxicologists study the impacts of chemicals on nonhuman organisms such as fish, birds, terrestrial animals, and plants.[2]

Regulatory toxicologists use scientific data to decide how to protect humans and animals from excessive risk. Regulatory toxicologists aim to protect the public from chemical exposure by establishing regulatory standards for food, drugs, water, air, and insecticides, to name only a few. Government bureaus such as the U.S. Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA) employ regulatory toxicologists.[2,3]

Routes of Exposure

Toxicants can harm an organism only if they are absorbed by the organism and reach the organs that are the target of their toxicity. This can happen through three routes:

- ingestion
- inhalation
- absorption through the skin

In humans and other animals, toxicants usually affect one or more target organs such as the lungs, skin, or gastrointestinal tract. For example, if a person inhales asbestos fibers, the fibers get stuck in the airways of the lungs and irritate the lung lining, causing lung impairment over time. Dermatitis can result if the asbestos fibers irritate skin cells.

Sometimes the toxicant crosses from the external environment of the lung, skin, or gastrointestinal tract into the bloodstream.[1] Many parts of the human body are designed to absorb chemicals quickly and effectively. The stomach, intestines, and colon absorb nutrients from our diet. These organs easily absorb nutrients and other chemicals because of their large surface area, thin diffusion distance, and high blood flow. The lungs also are designed for rapid absorption. Chemicals that are inhaled are quickly absorbed into the bloodstream through the thin walls of the air sacs in the lungs. The skin protects the body from harmful agents in the environment. However, the skin is in direct contact with the environment. While the dense outer layer of skin cells is a good barrier to chemical absorption, it is not perfect, even when intact. When the skin is cut or abraded, it absorbs chemicals very rapidly.[4]

Students' Misconceptions About Chemicals

Students often harbor misconceptions about chemicals. When asked what a chemical is, rather than define the word, students tend to give examples of synthetic, toxic chemicals like pesticides. When asked to name some things made of chemicals, students list items such as shampoo, window cleaner, processed foods, and "fake sugar" (aspartame). Students believe that chemicals pollute rivers and air. Students often do not realize that natural substances in the world around them also are made of chemicals. When asked if it would be better if there were fewer chemicals in the world, one student replied that fewer human-made chemicals would mean less pollution. When pressed, students will agree that some synthetic chemicals, like a pain reliever, can be good; however, students also recognize that even "good" chemicals like pain relievers can be toxic if a person takes too much.[5]

Notes About Lesson 1

The purpose of this lesson is to help move students from the view that chemicals are toxic, synthetic substances that are bad for human health and the environment to the more inclusive view that all things in the environment, including their bodies, are made of chemicals. Some of both naturally occurring and synthetic chemicals can have a detrimental effect on human health and the environment, but many do not. Those that have a harmful effect on human health do so because they get into the body through inhalation, ingestion, and absorption.

In Advance

CD-ROM Activities	
Activity Number	**CD-ROM**
Activity 1	yes
Activity 2	yes
Activity 3	yes
Extension Activity	no

Photocopies		
Activity Number	**Master Number**	**Number of Copies**
Activity 1	Master 1.1, *Item Cards* Master 1.2, *Periodic Table of Elements* Master 1.3, *Elemental Composition of the Human Body*	1 set for the class 1 transparency (optional) 1 transparency
Activity 2	none	none
Activity 3	Master 1.4, *Questions for Case Studies* Master 1.5, *Case Studies of Routes of Exposure*	1 transparency 1 copy of Case Study #1 for each student; number of copies of Case Studies #2–5 varies; see *Preparation* for Activity 3
Extension Activity	none	none

Materials		
Activity 1	**Activity 2**	**Activity 3**
For the class: • CD-ROM • computers • overhead projector • transparency of Master 1.2, *Periodic Table of Elements* (optional) • transparency of Master 1.3, *Elemental Composition of the Human Body* • 12 samples of things made of chemicals[a] • 1 set of Item Cards, from Master 1.1, *Item Cards*[b] • 8 4-by-6-inch index cards **For each student:** • science notebook	**For the class:** • CD-ROM • computers • blue food coloring • 50-mL graduated cylinder • 50 mL of purified water • 50-mL or larger glass jar with a lid • 1 large shoe box with a lid[c] • variety of clothing in a large basket or box[d]	**For the class:** • CD-ROM • computers • overhead projector • transparency of Master 1.4, *Questions for Case Studies* **For each student:** • 1 copy of Case Study #1 for each student from Master 1.5, *Case Studies of Routes of Exposure*; copies of Case Studies #2–5; see *Preparation* for Activity 3 • science notebook

[a] Because everything in the environment is made of chemicals, any item will work, such as salt, sugar, lemon, soft drink, liquid soap, window cleaner, shampoo, apple, rock, leaf, chair, and water. Use the chemicals students test in Lesson 2 (see *Preparation* for Activity 3 on page 28), plus others that do and do not fit students' concept of chemical.
[b] Item cards depict objects that are too big for the materials table or are potentially dangerous substances that students should consider when they choose items made of chemicals.
[c] Make sure that the glass jar fits inside the shoe box.
[d] Collect clothing such as elbow pads, knee pads, shorts, T-shirt, long-sleeved shirt, pants, different kinds of hats, hip waders, boots, sandals, sneakers, socks, sunglasses, protective goggles, ear and nose plugs, paper mask, mittens, gloves, and latex gloves.

PREPARATION

Activity 1

Arrange for students to have access to computers.

Collect samples of things made of chemicals. Place them on a materials table.

Tip from the field test: To make gathering the materials easier, ask students to bring in one item they think is made of chemicals and one they think is not made of chemicals.

Duplicate and cut out the Item Cards from Master 1.1, *Item Cards*. Fold them in half to make tent cards. Place the Item Cards on the materials table with the things made of chemicals.

Fold the index cards in half to make tent cards and label them with one of the following titles:

- made of chemicals
- not made of chemicals
- synthetic
- naturally occurring
- toxic
- nontoxic
- good
- bad

Make a transparency of Master 1.2, *Periodic Table of Elements* (optional).

Make a transparency of Master 1.3, *Elemental Composition of the Human Body*.

Activity 2

Arrange for students to have access to computers.

Make 50 mL of a mystery chemical:

- Measure 5 mL of blue food coloring into a 50-mL graduated cylinder.
- Add purified water to the graduated cylinder until you have 50 mL of blue solution.

Pour the mystery chemical into a 50-mL or larger glass jar and screw on the lid tightly. Place it inside the shoe box. Place the shoe box behind your desk.

Ask students to bring in articles of clothing. Place them and any you have gathered in a basket or box behind your desk.

Activity 3

Arrange for students to have access to computers.

Make a transparency of Master 1.4, *Questions for Case Studies*.

Duplicate Case Study #1 from the Master 1.5, *Case Studies of Routes of Exposure*, 1 for each student. Decide whether each student or teams will complete Case Studies #2–5 and duplicate the appropriate number.

Procedure

ACTIVITY 1: WHAT IS A CHEMICAL?

1. **Place the samples of things made of chemicals and the Item Cards on the materials table.**

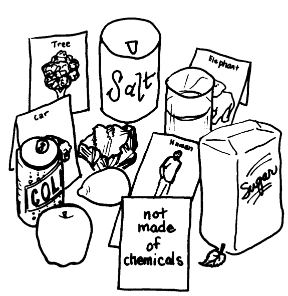
2. **Ask the students to look at the materials table and select one thing that they think is made of chemicals and one thing they think is not made of chemicals. Direct students not to remove the items, but to record the name of the items in their science notebooks.**

   Tip from the field test: In large classes where it might be difficult for students to see the materials, prepare a list of the names of all the materials and make a copy for each student. Instruct students to circle those materials on the list that are made of chemicals.

   You might find that students want more information. They might want to know what you mean by "made of chemicals." They might want you to be more specific about whether they should consider only synthetic items or those that may be toxic. Acknowledge that you have given them limited information, but ask them to do their best to make their choices. Do not provide any assistance at this time.

3. **Once all the students have recorded the items in their notebooks (or circled the items on their list), ask each student to name one item that is made of chemicals and one that is not. As students tell you their choices, stand by the materials table and separate the items according to student choices into two categories: made of chemicals and not made of chemicals. Continue until all students have shared their ideas. Use two of the tent cards to label the two categories: "made of chemicals" and "not made of chemicals."**

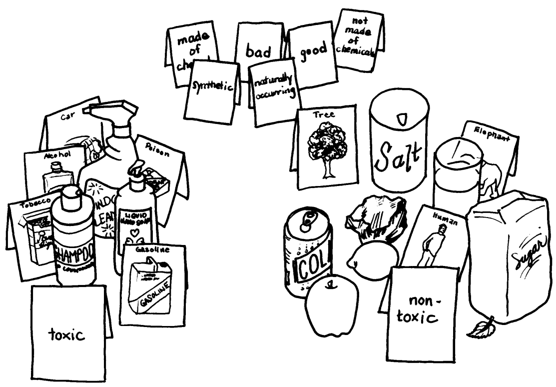
This activity provides you with a good assessment of students' prior knowledge of the concept of chemicals.



4. **Direct students to look at the groups of substances they think are and aren't made of chemicals. Conduct a discussion by asking questions similar to these:**

   - **Why do you think these are (or are not) chemicals?**
   - **Can you redivide these items into several different categories, such as synthetic (made by people) or naturally occurring? Good for humans or the environment or bad for humans or the environment? Toxic (harmful) or nontoxic (not harmful)?**
   - **Can a natural substance be made of chemicals?**
   - **Can a synthetic substance not be made of chemicals?**
   - **Is a natural substance always nontoxic, or a synthetic substance always toxic?**

   As you conduct this discussion, rearrange the items on the table several times and use new tent cards to label the new categories: "synthetic" or "naturally occurring"; "toxic" or "nontoxic"; and "bad" or "good."



Content Standard B: …There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances we encounter.

5. **As you progress through the discussion in Step 4, students may realize that they do not know a useful definition for "chemical." Have this definition ready for them:**

   chemical: any substance that is made of specific elements combined into molecules

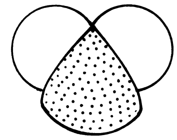
6. **As a class, view the segment from the CD-ROM titled *Everything Is Made of Chemicals.***

   To view the segment, load the CD (see Installation Instructions on page 13) and go to the main menu. Click on *Chemicals, Chemicals, Everywhere* and select the segment titled *Everything Is Made of Chemicals.*

Note: If you do not have access to a projection screen for the CD-ROM, set up a computer center where students can view the CD-ROM on their own or in small groups at a later time. At this time, display the transparency of Master 1.2, *Periodic Table of Elements,* and discuss the following:

- **Ask students to consider one substance, water, in light of the definition. Is water made of elements combined into molecules?**

Students are familiar with the molecular composition of water: H_2O. Point out the elements hydrogen and oxygen on the periodic table.


Water

- **Help students recognize that sugar and salt also are made of a combination of elements that form molecules.**

Table sugar is a crystalline carbohydrate, $C_{12}H_{22}O_{11}$. Salt is sodium chloride, NaCl.

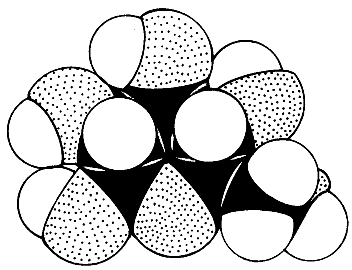


Table sugar

7. **After viewing the CD-ROM or discussing the periodic table, continue by helping students recognize that all of the substances on the materials table are made up of specific molecules, even if the students don't know exactly what they are. Once they recognize this, students will begin to realize that all things are made of chemicals. Ask students to tell you, based on their new understanding, some other things around them that are made of chemicals. Let students continue until you see that they understand that everything around them, or everything in their environment, is made of chemicals.**

8. **To make sure that the students understand that they, too, are made of chemicals, display a transparency of Master 1.3, *Elemental Composition of the Human Body*. Let your students know that these elements are combined in many different ways to form thousands of different chemicals that make up the human body.**

9. **Discuss with students how their original idea about what a chemical is, which led them to their choices in Step 2, is different from the scientific definition of a chemical. Why do they think this is so?**

Students will recognize that they hear most about the chemicals that are toxic to humans or the environment. Because of this, students often think of chemicals as only those synthetic substances that are introduced to the environment and cause harm. Help students recognize that they also know a lot about synthetic chemicals that are beneficial to humans, such as pain relievers and other medicines. They also know about naturally occurring chemicals that are toxic to humans, such as hydrogen sulfide (sewer gas) and carbon monoxide, to name two. By the end of the discussion, help students recognize that chemicals can be synthetic or naturally occurring and make up every substance on Earth, even our bodies.

Bridge to Activity 2 by helping students understand that many chemicals, both synthetic and naturally occurring, can be beneficial to humans and the environment. Those chemicals that are not beneficial are the ones we want to know more about so that we can protect ourselves and the environment from harm.

ACTIVITY 2: PROTECT THE TOXICOLOGIST

1. **Bring out the shoe box from behind your desk. Tell the students that inside the shoe box is a mystery chemical. Discuss with the students some things they might want to know about the contents of the shoe box before they open it. Ask why it would be important to know these things.**

   Be sure that students recognize that they would want to know what the chemical is (for example, name; naturally occurring or synthetic; solid, liquid, or gas; how much of the chemical is in the container). Most importantly, they would want to know if it is toxic to the humans in the classroom because they would not want to accidentally expose themselves to a harmful substance.

Content Standard G: Students should develop an understanding of science as a human endeavor.

2. **Tell the students that they are asking a lot of the same questions that a toxicologist might ask. Write the word *toxicologist* on the board. Ask students to identify the root of the word, *toxic*. Underline it on the board. Tell students that toxicologists are scientists who are specially trained to examine the nature of the harmful effects of chemicals on living organisms. They try to understand which chemicals are toxic to living organisms and in what amounts those chemicals are toxic. While they want to know which chemicals might cause death, they also are interested in other toxic effects, such as disease, tissue damage, genetic alterations, and cancer.**

3. **Select a student (or ask for a volunteer) and tell the student that he or she is a toxicologist. Tell students that you want the student toxicologist to open the shoe box and look at the mystery chemical, but you do not know anything about the chemical. The student toxicologist needs to protect himself or herself in case the chemical is harmful to humans.**

   Present to the class the large basket or box of clothing. Ask the class to work together to think of items that the toxicologist should wear for protection from exposure to the chemical. Find items in the basket as students suggest them and give the items to the student toxicologist to put on until he or she is dressed in a protective manner that satisfies the class.

Tip from the field test: You may not have access to a wide variety of true protective gear. Use regular clothing, but ask students what problems there might be with certain items. For example, if students suggest that the toxicologist's hands need to be covered, you could pull out a pair of mittens. Direct the toxicologist to put on the mittens, but ask the class if the mittens are the best choice and why or why not.

As students select an item, question why a toxicologist needs to wear it. Probe for understanding that a toxicologist is concerned about exposure to a chemical by eating or drinking it, by breathing it, and by absorbing it through the skin. Look to see whether the student toxicologist's skin, eyes, mouth, and nose are covered.

This activity is engaging and fun for the students, but it also helps you assess students' knowledge of an important concept of toxicology: routes of exposure.

4. **Once the student toxicologist is dressed protectively, explain that real toxicologists know that chemicals can enter the body in three ways, called routes of exposure: through the mouth by ingestion, through the nose and mouth by inhalation, and through the skin by absorption. Write the list of the three routes of exposure on the board:**

Routes of Exposure

✓ ingestion

✓ inhalation

✓ absorption through the skin

Use the list as a checklist and ask students if they think the student toxicologist is adequately protected from all routes of exposure. If not, have them adjust the protective clothing or suggest useful clothing that is not in the basket.

Point out that the mystery chemical could be a solid, a liquid, or a gas. Discuss each form of a chemical and how the form can help determine which routes of exposure are most likely. For example, a gas might be easily inhaled as soon as the container is opened, while a solid might only be harmful if a person touches it or ingests it. In addition, chemicals can change form. For example, dry ice is solid carbon dioxide that quickly becomes a gas. Liquid mercury can evaporate into a gas, causing exposure by inhalation.

Thank the student toxicologist and ask him or her to return the protective clothing to the basket.

5. **Tell students that people who work around toxic chemicals protect themselves in ways similar to those the students suggested for the student toxicologist. Provide time for students to view the segment *Ride Along with HAZMAT* on the CD-ROM.**

To find the segment, load the CD and go to the main menu. Click on *Chemicals, Chemicals, Everywhere* and select *Ride Along with HAZMAT*.

Photo: Corel

6. **Tell the students that you will dress protectively and remove the mystery chemical from the container when they are not in the room (because they are not protected). Let them know that they will be able to examine the chemical during the next class if you decide it is safe to do so.**

ACTIVITY 3: CASE STUDIES OF ROUTES OF EXPOSURE

1. **Set up the class so that each team of students has access to a computer, such as in a computer lab. Instruct teams to do the activity titled *What's Wrong Here*? on the CD-ROM. Circulate around the room and listen as groups work through each situation.**

To view the activity, load the CD and go to the main menu. Click on *Chemicals, Chemicals, Everywhere* and select *What's Wrong Here?*

Content Standard E: Students should develop understandings about science and technology.
Content Standard F: Students should develop understanding of natural hazards, and risks and benefits.
Content Standard G: Students should develop understanding of science as a human endeavor.

2. **Tell students that now they will consider some true chemical exposures. Display a transparency of Master 1.4, *Questions for Case Studies*. Then, distribute a copy of Case Study #1 from Master 1.5, *Case Studies of Routes of Exposure*, to each student.**

3. **Ask students to work in teams and to read Case Study #1. Instruct them to answer the questions on the transparency in their science notebooks.**

4. **Once teams have read and answered the questions about Case Study #1, conduct a class discussion about the case study by answering the questions on the transparency.**

Sample Answers to Questions for Case Study #1 on Master 1.4

Question 1. What happened? Where did it happen? When did it happen?

A Dartmouth College scientist died of mercury poisoning in 1997 in New Hampshire after being exposed to the chemical in 1996.

Question 2. What chemical was involved?

The chemical was dimethylmercury (die-METH-ul-MER-kyoo-ree).

Question 3. What was the route of exposure?

The route of exposure was absorption through the skin.

Question 4. What were the symptoms of toxicity?

The symptoms of toxicity were permanent nervous system damage, numbness of fingers, unsteady walking, difficulty speaking, blurred vision, hearing problems, coma, and death.

Question 5. How could a person have prevented his or her exposure to the chemical?

Answers will vary. The researcher used precautions thought to be adequate at the time.

Question 6. Have any changes occurred since the incident? Describe them.

Researchers now know that dimethylmercury can seep through latex gloves. They now use neoprene gloves with long cuffs or wear two pairs of gloves, one of them laminated and one of them heavy duty.

5. **There are four more case studies, two describing chemical exposure through inhalation and two describing chemical exposure through ingestion. Continue to have students read, discuss, and answer the questions about each case study.**

   Tip from the field test: Give a different study to each team and ask the teams to read their study. Then, instruct teams to present their case study to the class. Teams can explain their case study and answer the questions from the transparency so that everyone in the class learns about the case and discusses the route of chemical exposure. The case studies vary in length, allowing you to individualize the reading assignment for students of varying reading abilities.

This is a good time to assess your students' understanding of the three ways chemicals can enter the human body and cause harm: ingestion, inhalation, and absorption.

Sample Answers to Questions for Case Studies #2–5 on Master 1.4

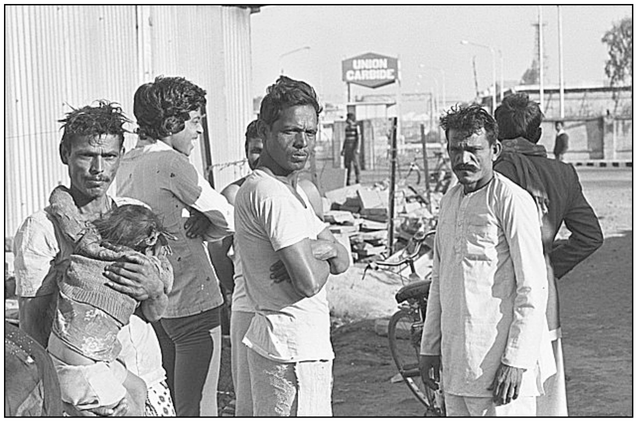
Case Study #2

Question 1. What happened? Where did it happen? When did it happen?

Gas leaked from a chemical plant in 1984 in India.

Question 2. What chemical was involved?

The chemical involved was methylisocyanate (METH-ul-EI-soh-SIE-uh-nate).



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Question 3. What was the route of exposure?

The routes of exposure were inhalation and absorption through the eyes and the nose.

Question 4. What were the symptoms of toxicity?

The symptoms of toxicity were eyes and lungs burning, vomiting, lung impairment, loss of motor control, neurological disorders, and damaged immune system.

Question 5. How could a person have prevented his or her exposure to the chemical?

Answers will vary. Students should recognize that people who lived in Bhopal had little choice over their exposure. People could have made the choice not to live near a chemical plant.

Question 6. Have any changes occurred since the incident? Describe them.

The chemical plant was sold to a company in Calcutta. Proceeds from the sale supported hospitals and clinics in Bhopal.

Case Study #3

Question 1. What happened? Where did it happen? When did it happen?

Jane had lead poisoning; it happened in her home during her first two years of life.

Question 2. What chemical was involved?

The chemical involved was lead.

Question 3. What was the route of exposure?

The route of exposure was ingestion.

Question 4. What were the symptoms of toxicity?

The symptoms of toxicity were abdominal pain, constipation, vomiting, and lethargy; in severe cases, learning disabilities, decreased growth, hyperactivity, impaired hearing, and even brain damage can occur.

Question 5. How could a person have prevented his or her exposure to the chemical?

Prevention for children includes annual blood tests to check lead levels; clean play areas, floors, windowsills, and hands; professional paint removal; and drinking of milk.

Question 6. Have any changes occurred since the incident? Describe them.

Students can assume that Jane's mother acted on the doctor's suggestions for minimizing the family's exposure to lead.

Case Study #4

Question 1. What happened? Where did it happen? When did it happen?

Jimmy Green died from sniffing gasoline in the spring of 1999.

Question 2. What chemical was involved?

The chemical was gasoline.

Question 3. What was the route of exposure?

The route of exposure was inhalation.

Question 4. What were the symptoms of toxicity?

The symptoms of toxicity were short-term memory loss, hearing loss, arm and leg spasms, permanent brain damage, liver and kidney damage, and death.

Question 5. How could this person have prevented his or her exposure to the chemical?

Jimmy Green voluntarily exposed himself to gasoline fumes. He could have prevented his exposure by choosing not to sniff gasoline.

Question 6. Have any changes occurred since the incident? Describe them.

Parents and students are now informed of the dangers of inhalants.

Case Study #5

Question 1. What happened? Where did it happen? When did it happen?

In 1971, more than 6,500 people were poisoned in Iraq.

Question 2. What chemical was involved?

The chemical was methylmercury (METH-ul-MER-kyoo-ree).

Question 3. What was the route of exposure?

The route of exposure was ingestion.

Question 4. What were the symptoms of toxicity?

The symptoms of toxicity were nervous system disorders.

Question 5. How could a person have prevented his or her exposure to the chemical?

If people had been better informed, they would have planted the seed instead of eating it.

Question 6. Have any changes occurred since the incident? Describe them.

No changes were mentioned in the case study, but students might discuss the need for better warning labels and instructions for grain shipped between countries.

Extension Activity

Ask students to find current event stories in newspapers, magazines, or television programs that talk about chemical exposure. Challenge students to find one event that involves a chemical exposure that harms humans or other living things and one that involves a chemical exposure that benefits humans or other living things.

You will be able to use a chemical exposure described in these articles in the extension activity in Lesson 5.

Tip from the field test: If students in your school are required to bring in current event articles for several other classes, coordinate with teachers making similar assignments so that students are not duplicating efforts. Alternatively, collect articles yourself and display them in the classroom.

Teacher's Guide

◂ Return to Lesson Plans

Lesson 5—What Is the Risk?
Elaborate

PDF Files for Printing

At a Glance

Overview

Students apply their growing understanding of the concepts of toxicology (dose, response, individual susceptibility, potency, and threshold) to their discussion of the 1950s tragedy in Minamata, Japan. They learn how to assess the risk of people to specific chemical hazards and make decisions about how to manage that risk.

Major Concepts

People can make some choices about chemical exposure; however, some exposure is controlled at a level other than an individual one. Collective groups of people, such as communities and governments, seek to control chemical exposure on a community or global level.

Objectives

After completing this lesson, students will

- use their knowledge about dose, response, individual susceptibility, and route and frequency of exposure to understand a historical situation involving hazardous chemical exposure;
- assess the risk to people in Minamata of mercury poisoning using a risk assessment flow chart;
- compare their own risk of mercury poisoning with that of the people of Minamata; and
- understand the kinds of critical choices people make about chemical exposure and that some exposure is controlled at a level other than an individual one, such as the community or global level.

Background Information

The Minamata Case Study

When people living in Minamata, Japan, in the 1950s began slurring their speech occasionally or dropping their chopsticks at a meal, no one thought much of it. Some people cruelly laughed, claiming their clumsy friends were acting like the cats that were "dancing" strangely in the street and falling to their death in the sea. When it seemed like more and more people were suffering from the mysterious lack of coordination, the community began to realize that something was seriously wrong. But, people did not know that they were seeing the first signs of a debilitating nervous condition caused by ingesting mercury.[1]

We now know the tragic story of Minamata. The Minamata Bay was polluted with the industrial waste from the Chisso Corporation, which manufactured acetaldehyde used to make plastics. The mercury that the company used in the production process was discharged into the bay, incorporated into bacteria, and passed through the food chain to people living in the area. The people in the town were slowly being poisoned by their most important food source: fish.

The consequences of such blatant polluting seem obvious to people today. But at the time, science had not yet documented the hazards of mercury, and environmental awareness was not pervasive. In fact, the Minamata case has become a classic lesson in the tragedy of industrial pollution and the need to anticipate the unexpected consequences of introducing chemicals into the environment. Although the story is now half a century old (and "ancient history" for today's middle school students), it has a well-documented cause and effect, as well as a resolution. In this way, it provides a good model for teaching about risk assessment and management that students can apply to their analysis of current exposures to chemicals.

Photo: W. Eugene Smith and Aileen M. Smith

Risk Assessment

Today, when toxicologists study the extent and type of negative effects associated with a particular level of chemical exposure, they can use what they learn to assess the threat of that chemical to people's health. To do this, toxicologists measure a person's risk of exposure to the chemical. For example, even though dioxin is considered the most toxic synthetic chemical known, it does not pose the greatest risk to humans because the potential for significant dioxin exposure is quite small. In addition, while the lethal dose of a chemical is an important measurement to make, it is quite possible that a chemical will produce a very undesirable toxic effect at doses that cause no deaths at all. These lower doses may be the amount to which people are regularly exposed.

How a person is exposed to a chemical also determines the factor of risk. In the case of a single exposure, the amount of chemical and the way the body is known to respond to the chemical determine the severity of the toxic response. In the case of repeated exposures to a chemical, it is not only the amount of chemical that counts, but also the frequency of exposure. If the body is able to rid itself entirely of the chemical before the next exposure, it is possible that each exposure is akin to a single exposure to the chemical. If, however, the body still retains some of the chemical from the previous exposure, accumulation of the chemical can occur and eventually can reach toxic levels, even if each exposure is small.

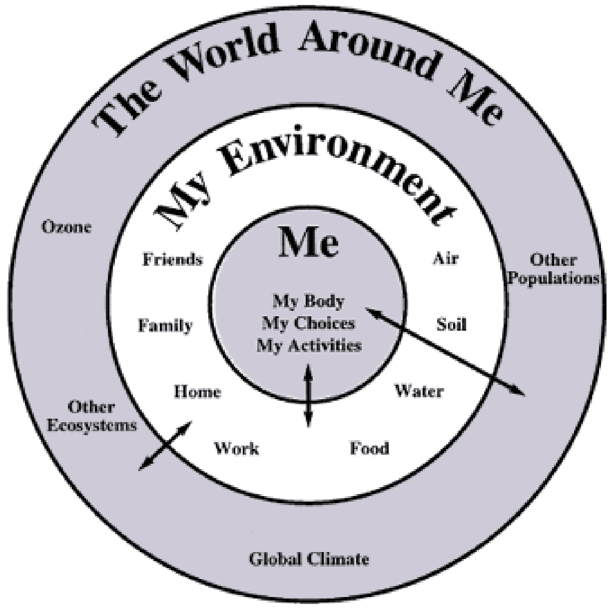
Many of the measurements that guide toxicologists in their assessment of human risk are based on studies of animals other than humans. This fact, coupled with the individual susceptibility of different members of the human population, makes it difficult to know with absolute certainty the level of risk to which each individual is exposed. With adequate information, however, toxicologists can predict the health risks associated with specific chemical exposures and help the human population make informed decisions about how to limit those exposures.

Managing Risk

The built-in uncertainty of risk assessment makes it essential for people to possess enough knowledge to make decisions about their own exposures to chemicals. With adequate knowledge, individuals can make decisions concerning their exposure to tobacco smoke, pollutants in water, and chemicals in food. By modifying their individual behavior, people can have some control over the chemicals they absorb into their body.

Not all decisions about chemical exposure and control can be made at an individual level, however. Local, national, and global communities of people are exposed to chemicals over which they have very little individual control. People are exposed to air pollution from factories and cars or chemicals used by farmers on crops without any individual consent. To manage a community's risk from chemicals in the environment, organizations and agencies set standards to protect human health.

There are choices about chemical exposure over which individuals have control (represented by the inner circle in the adjacent diagram). Individuals are also affected by their immediate environment (their friends and family, as well as the air, soil, and water around their homes and workplaces); the middle circle of the diagram describes influences on an individual over which he or she has less control. Finally, the outer circle describes the world that surrounds individuals over which they have little control but that can have an impact on individuals. The arrows between each concentric circle indicate that individuals, their environment, and the world at large all affect each other.



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One step in community risk management is to determine how much risk is acceptable to people. If the chance that exposure to a particular chemical causes cancer is only 1 in 1 million, people often are less concerned than if the chance is 1 in 10. The picture becomes more complicated when societal issues weigh in. Is the exposure voluntary (as in smoking cigarettes) or involuntary (as in pollution from a factory)? Does it occur in the workplace or at home? Are there acceptable alternatives to the use of the toxic chemical? How would use of a safer chemical change the economic picture?[2]

To establish some individual control over community management of chemical exposure, people can choose to be involved with organizations and agencies that are concerned with the prevention of toxic chemical exposure on a community level.

Notes about Lesson 5

In this lesson, students have the opportunity to apply many of the concepts of toxicology to a scenario that involved toxic chemicals in Minamata, Japan. By looking at a situation from the 1950s, students can recognize how far scientists and the general public have come in their understanding of chemical hazards and their knowledge of how to minimize risk from these hazards. Students can begin to identify situations in their own lives in which they make conscious decisions to limit their chemical exposure and those over which they have little control.

In Advance

Web-Based Activities

Activity Number	Web Version
Activity 1	Yes
Activity 2	No
Extension Activity	No

Photocopies

Activity Number	Master Number	Number of Copies
Activity 1	Master 5.1, *Risk Assessment and Management* Master 5.2, *Minamata Disease*	1 transparency 1 for each student
Activity 2	Master 5.1, *Risk Assessment and Management* Master 5.2, *Minamata Disease*	1 transparency 1 for each student
Extension Activity	None	None

Materials

Activity 1	Activity 2	Activity 3
For the class: • Web site address • computer with Internet access • overhead projector • transparency of Master 5.1, *Risk Assessment and Management* • plain paper **For each student:** • 1 copy of Master 5.2, *Minamata Disease*	**For the class:** • overhead projector • transparency of Master 5.1, *Risk Assessment and Management* • plain paper **For each student:** • 1 copy of Master 5.2, *Minamata Disease*	**For the class:** • current event stories students began collecting in Lesson 1, Extension Activity

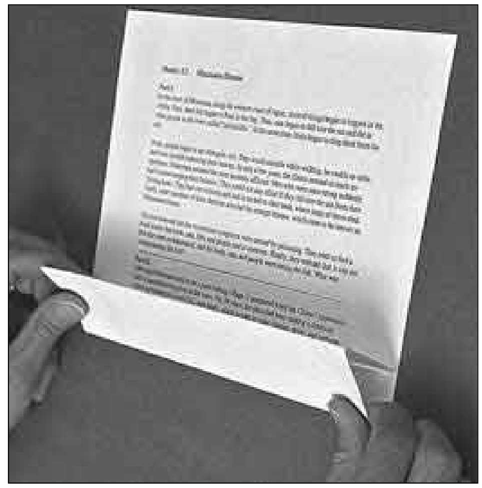
Activity 1	Activity 2	Activity 3

PREPARATION

Activity 1
Arrange for students to have access to computers.

Make a transparency of Master 5.1, *Risk Assessment and Management*.

Duplicate Master 5.2, *Minamata Disease*, one for each student. To allow students to read only small amounts of the information at a time, fold along the dashed lines.



Activity 2
Gather the same materials used in Activity 1.

Extension Activity
Remind students to bring in the current event stories they began collecting in Lesson 1.

Be sure to have a transparency of Master 5.1, *Risk Assessment and Management*.

Procedure

ACTIVITY 1: PEOPLE AT RISK

1. Remind students that there are chemicals in the environment that cause health problems for humans. Tell students that toxicologists study the extent and type of health problems associated with a particular level of chemical exposure and use what they learn to assess the threat of that chemical to the health of people in particular situations. This kind of analysis is called a *risk assessment*. Display the top half of a transparency of Master 5.2, *Risk Assessment and Management*.

2. Distribute the folded sheets made from Master 5.2, *Minamata Disease*. Tell students that they are going to practice the steps to making a risk assessment by using a well-known case from Japan in the 1950s. Instruct students to read Part I of Master 5.2. Then, discuss the answers to the questions in Step 1 on the *Risk Assessment and Management* transparency.

Content Standard F: Students should develop understanding of personal health, natural hazards, and risks and benefits.

- **Is a new health problem present?**

  Yes. Fish, cats, and birds were sick and dying. Also, people were acting strangely.

- **What are the symptoms?**

  People were stumbling, unable to write, fumbling with their buttons, having difficulty balancing, falling from boats, suffering from convulsions, and dying.

- **What do the affected individuals have in common?**

  Many work as fishermen or were in the families of fishermen.

Once students have answered the questions on the transparency, ask them to offer ideas about what they think was contaminating the fish.

3. Instruct students to unfold the first fold, revealing Part II. Ask them to read the paragraphs and then answer the questions in Step 2 of the Risk Assessment on the transparency.

- **What is causing the problem?**

  Pollution was contaminating the fish with mercury, and people were getting sick when they ate the fish.

- **What is the source of the problem?**

Photo: W. Eugene Smith and Aileen M. Smith

The Chisso Corporation was dumping the mercury, so the company was the source of the problem. It might be interesting to discuss the role the community had in allowing the pollution of the bay to continue by accepting compensation for poor fishing conditions. Could the townspeople have demanded cleaner water instead of being satisfied with a monetary solution to the problem of fewer fish for harvest?

Once students have answered the questions on the transparency, ask them to suggest answers to the question at the end of Part II: What made this contamination of the fish so dangerous to humans?

Content Standard E: Students should develop understandings about science and technology. Perfectly designed solutions do not exist. All technological solutions have tradeoffs, such as safety, cost, efficiency, and appearance. . . . Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

4. Instruct students to unfold the next fold, revealing Part III. Ask students to read the paragraph and then answer the questions in Step 3 of the risk assessment.

- **What are the sources of exposure to the chemical?**

  People were exposed to mercury by eating contaminated fish. The contamination of the fish was serious because it was a primary food source for the community.

- **How much exposure are people in the area receiving?**

  People in Minamata, especially fishermen and their families, ate fish often. They were getting a small amount of mercury often over a period of time. Any amount of contaminated fish over 30 pounds per year is likely to provide a harmful exposure to mercury.

- **Is the exposure acute or chronic? (Is it likely to happen only once, or often over the course of time?)**

  The exposure to mercury happened in Minamata over a long period of time: It was a chronic chemical exposure.

5. Ask students *not* to unfold the last fold until directed to do so during the next activity. Discuss the information from the reading and answer the concluding question on the risk assessment: How great is the risk to people?

Because of their dependence on fish as a primary source of food, the potential risk of mercury poisoning from contaminated fish for people living in Minamata was very high.

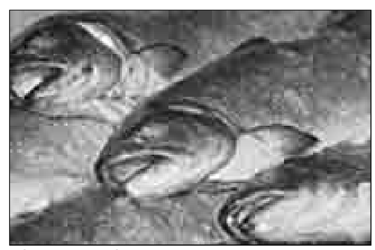


Photo: Corel

6. Play the video segment on the Web site that describes the Minamata story.

Open the Web site in your browser (see instructions for using the Web site). From the main page, click on *Web Portion of Student Activities*, then select *Lesson 5—What Is the Risk?* Play the video documentary for the students.

Because the time period and geographic location of the Minamata tragedy are so far removed from students' experiences, the visual representation of the story on the Web site helps it come alive for students.

ACTIVITY 2: WHAT IS *YOUR* RISK?

1. Remind students that mercury is used today in thermometers and batteries. (Although newer thermometers now use red alcohol, many old ones contain mercury.) Tell students that although they do not live in Minamata in the 1950s, inappropriate disposal of items containing mercury poses a threat to their environment, even today. Since garbage either is incinerated or covered up in landfills, mercury can make its way into the environment through emission of burning gases into the air or groundwater contamination. Fish contaminated with mercury can make their way into the food supply.


Photo: Corel

2. Ask students how they think they can avoid mercury poisoning from contaminated fish.

Most students will say that they could stop eating fish, thereby eliminating their risk just by avoiding exposure to the mercury-contaminated fish. Some students may indicate that the risk of mercury poisoning provides a great excuse to avoid a less-than-favorite food: fish.

Ask students if it is always possible to avoid a chemical in order to eliminate possible exposure. What about a chemical in the air? Could students choose not to breathe in order to avoid exposure to an air pollutant?

This question brings up the issue of control. If your food supply is varied enough, you can choose not to eat fish and still remain healthy. (This might not be an option for an island population that depends on fish for protein.) You cannot, however, choose not to breathe as a way to avoid exposure to an air pollutant. You would need to find other ways to limit your exposure to the air pollutant, like staying inside, not exercising outside, or wearing a mask that filters the air.

3. Tell students that one of the reasons for understanding the role of toxicology in human health is to empower the students to make choices that decrease their risk of becoming ill due to exposure to harmful chemicals. Once they know the risk from a chemical exposure, they can manage their risk by deciding how to deal with the risk. Walk the students through the steps of Risk Management on the bottom half of the transparency of Master 5.1, *Risk Assessment and Management*. Contrast the situation in Minamata, Japan, in the 1950s with the life of today's typical U.S. middle school student.

First, ask the students to think about risk assessment:

- **What is a person's risk of mercury poisoning?**

  Because of their dependence on fish as a primary source of food, the potential risk for a person living in Minamata in the 1950s was high. For today's middle school students, the risk is relatively low. The average middle school student does not consume enough fish to pose a problem, and most of the fish is commercially caught in regulated waters. Only a middle school student who lived near contaminated water and regularly ate the fish from the contaminated water would be at a higher risk.

  Then, continue answering the questions in the Risk Management section of the transparency:

- **How do the people involved perceive the risk? Are their perceptions accurate?**

  Possible answers: At first, Minamata residents did not know of the risk or worry about it. Once they began to see the effects of mercury poisoning, they perceived the risk as very serious. Their perceptions were accurate: Their primary food source was contaminated by industrial pollution, and that pollution was having a direct effect on the health of the community.

  Middle school students should perceive their risk as minimal. If a student perceives his or her risk as high, that perception would not be accurate according to the risk assessment above.

- **Who is responsible for the harmful substance and its presence in the environment? What role does the responsible party have in any cleanup?**

  Allow time for students to discuss who they think was responsible for the situation in Minamata and what they think the responsible party should have done. Then, instruct them to unfold the last fold on Master 5.2 and read Part IV.

  The Chisso Corporation was responsible for discharging polluted effluent into the bay. The corporation ultimately was held liable for its negligence in the 1970s. More complicated, however, are the social and economic pressures that influenced the placement of the plant in Minamata: People in the fishing village were interested in progress and enjoyed the prosperity that the industry brought to the town.

  Middle school students could be indirectly responsible for some of the mercury contamination in their local area because of the way they dispose of batteries. Students and family members can take responsibility for disposing of potentially harmful materials in a safe way and using safer alternatives, such as rechargeable batteries.

- **What are the benefits and tradeoffs that a person must weigh when making a decision about the risk?**

  Fish provide many health benefits to the cardiovascular system and to brain development. The dietary proteins that fish provided to the residents of Minamata were very important to good health. However, we now know that mercury poisoning from eating contaminated fish results in serious brain damage. The U.S. Environmental Protection Agency has advised that there are health benefits to eating fish and that consumption of fish should continue, but at a rate not to exceed 30 pounds per year. Because middle school students rarely reach an annual level of consumption of 30 pounds of fish, they can enjoy all the healthy benefits of eating fish without being concerned about any negative tradeoffs.

- **What action should people take to minimize their risk? Can the risk be managed by individuals, the community, and/or governments?**

In Minamata, industrial manufacture of acetaldehyde needed to stop. The corporation still operates in Minamata but produces liquid crystals, preservatives, fertilizers, and other chemicals. Over several years, 1.5 million cubic meters of contaminated sludge was dredged from the bay. Over the main dumping site, there now are museums, memorial sites, parks, and a study center. In 1997, the water in the bay was declared safe again for fishing and swimming. People have chosen to move away from Minamata to make their living elsewhere: The town has only 70 percent of the number of people it once had.

Middle school students can eat fish sensibly, dispose of mercury-containing products safely, and support organizations that provide hazardous waste cleanup in their communities. Regulatory agencies can measure mercury contamination in fish and regulate fishing or sales of fish from contaminated waters.

Before discussing the current event with the class, ask students to do a risk assessment individually. Collect students' written summaries and evaluate them for an understanding of the process of assessing risk. Then discuss the students' ideas for managing the risk.

Extension Activity

1. Review a local or current situation in which people are being exposed to a hazardous chemical. Use the *Risk Assessment and Management* transparency to discuss students' ideas about the level of risk for the community and ways to manage that risk.

Tip from the field test: This is a good time to go back to the current event articles the students have been collecting since Lesson 1. Choose one or two of the most interesting situations and assess risk for the population and decide how to manage the risk.

Because a current situation most likely will be unresolved, you will need to lead an open-ended discussion and help students recognize that there might not be answers for some of their questions at this time. This process of asking questions and not knowing the "right" answers is representative of the nature of science and scientific inquiry.

Content Standard G: Students should develop an understanding of the nature of science and the history of science.

◂ Return to Lesson Plans