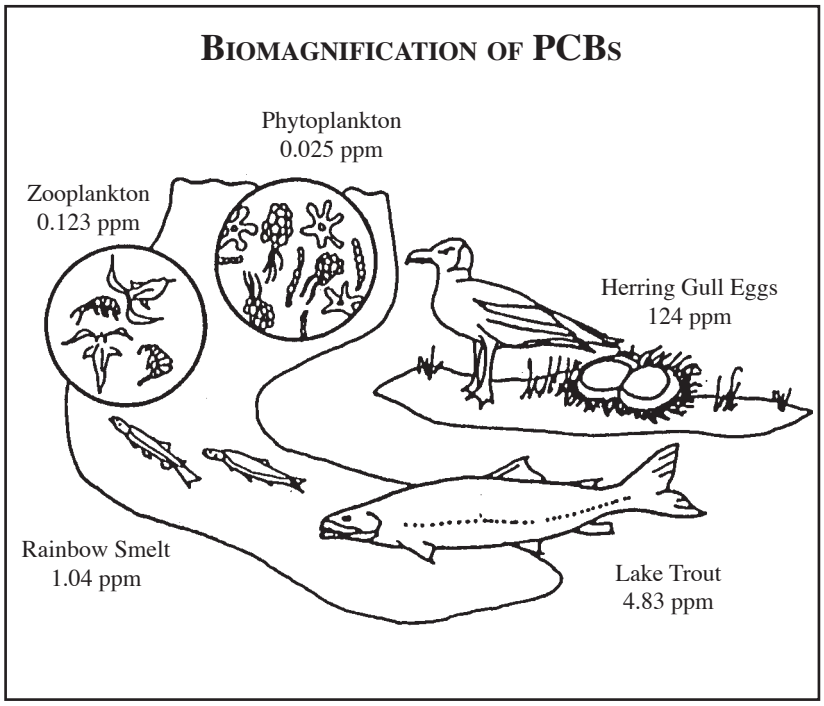
Activity B: Where do all the toxins go? (Internal View)

An unfortunate byproduct of the high standard of living enjoyed by developed nations is a heavy reliance on chemicals. Chemicals are used in agriculture and industry and are unintentional byproducts of many human activities. Many of the chemicals that we have become so dependent on are entering our Great Lakes as toxic fallout from the air.

In what ways do chemicals present a problem in the Great Lakes ecosystem? Not very often do we hear about massive kills from chemicals. The effects are much more subtle. Many chemicals enter the food chain at the lower end and accumulate and magnify within organisms throughout the chain. Those carnivores at the top of the food chain, including humans, have the highest levels of these toxins in their bodies. One of the foods that is popular with humans is fish — fatty fish such as trout and salmon accumulate the most toxins through the food chain, and larger fish are the most dangerous. People are warned not to eat fish that exceed a certain length (such as brown trout over 18 inches in Lake Ontario) and to restrict consumption of smaller fish of these species.

The characteristics of a chemical that determine whether or not it will be an environmental hazard are: its toxicity, its persistence, and its affinity for water. Chemicals that have no affinity for water tend to have an affinity for lipids (fats). They combine with the fatty substances in an organism's body, and if persistent, will remain with the organism until it dies or is consumed.

PCBs (polychlorinated biphenyls) are a class of toxic chemicals that appear in many Great Lakes fish. They were frequently used as coolants, especially around electric transformers, because they conduct heat but not electricity. All production of PCBs was stopped in 1976 after it was discovered how toxic they were. However, they do not break down in nature, and many products containing them are still around. As old transformers and other such equipment are discarded, PCBs may leak into the air or water. PCBs then enter the marine food chain and collect in the fatty tissues of fish. PCBs cause carnivores such as cormorants, and scavengers such as gulls, to develop reproductive problems or deformities.



The Great Lakes. An Environmental Atlas and Resource Book. Produced by Environment Canada and U.S. Environmental Protection Agency (1987 and 1995)

In this activity, iodine is used as an example of a fat-soluble compound. The iodine atoms associate themselves with oil (fat) molecules and cause a color change. In the lake environment, chemicals such as DDT and PCBs are fat soluble. They tend to be extracted from the lake water and concentrated in fatty substances in plants and animals. Carnivores, such as fish, eat other organisms that contain the toxins and accumulate the substances in their bodies. High concentrations of these chemicals are found in the belly fat and under the skin of fatty fish such as lake trout, salmon, and chub.

Source

This activity was originated by Michigan Sea Grant in its curriculum activity, "A fish fat phenomenon" (*Great Lakes Fishing in Transition*)

Materials

- Iodine crystals (8 per demonstration)
- Screw-top vial (about 75 ml)
- 20 ml water
- 20 ml vegetable oil
- Ohio Sea Grant Fact Sheet 007: *PCBs: Their history and our health*. (optional)

Earth Systems Understandings

This activity focuses on ESU 2 (stewardship), 3 (science processes), 4 (interactions) and 7 (careers).

Answers

a. The sugar dissolves.
b. The butter would not dissolve; it would stay in lumps.
c. Solubility refers to the ability of one substance to become evenly distributed in another substance.
d. Some of the iodine dissolves — some does not. The water turns light brown.
e. Iodine was extracted into the oil because iodine is more soluble in fat than in water. Since there is no more iodine in the water, the water clears up. The oil layer turns pink, indicating the presence of iodine.
f. Oil
g. The oil represents fat; water represents other bodily fluids (lood, saliva, sweat.).
h. PCBs accumulate in the fat.
i. They can't be washed out because the fats won't dissolve in these fluids.
j. To prepare fish safely, clean all the fat off before cooking, and broil the fish on a rack so that it doesn't cook in its own juices. Note that this method would not remove poison metals such as mercury, because they accumulate in muscle tissue.

OBJECTIVES

When students have completed this activity, they will be able to demonstrate how chemicals accumulate in fish fat, the biopathways of the toxins in the fish's body, and ways to prepare fish to avoid consuming the toxins.

PROCEDURE

1. Introduce the concept of solubility to the students. Ask the following questions:
   a. What happens to a teaspoon of sugar when you put it into a glass of water?
   b. What would happen to a pat of butter if you mixed it into a glass of water?
   c. What is meant by *solubility* ?

2. As a demonstration, put the iodine crystals in the vial with 20 ml of water. Tighten the lid, and allow the students to pass the vial around and shake it.
   d. What happened to the iodine when it was mixed with the water?

3. Open the vial and pour in 20 ml of vegetable oil. Replace the lid, and pass the vial around for more shaking.
   e. What happened when the oil is added? Why?
   f. In which substance is iodine more soluble, water or oil?
   g. What type of bodily substance in an animal does the oil represent? The water?
   h. Where do PCBs accumulate in fish and other animals?
   i. Why can't the PCBs be "washed out" by blood or urine?
   j. If you want to consume fish, but are not sure if it contains PCBs, how would you prepare it to be safe?

4. Distribute the fact sheet on preparing your catch (#007). If possible, have a student who is an experienced angler demonstrate proper fish cleaning. Other students should note where fat is found in the fish's body.

5. Gravid fish (full of eggs) carry most of their toxin load in the eggs. Discuss the implications of this for
   a. Using fish eggs as bait,
   b. Fish that feed on fish eggs, and
   c. The safest time to catch female fish.

6. The use of chemicals has become part of the lifestyle of people living near the Great Lakes.
   d. If all the toxic chemicals were eliminated from the environment, would everyone be pleased? Which professions would suffer without the chemicals? Which professions are impacted now by the presence of toxic chemicals?

EXTENSIONS

1. Investigate the existing and proposed cooperative regulations between the United States and Canada regarding protection of the Great Lakes environment. Do you feel that they are sufficient, or can they be strengthened?

2. Suppose a state or province decided to regulate commercial fishing so that consumers would receive fish with less chance of contamination. Use the activities titled "Which fish can we eat?" and "How should the public health be protected?" to role play the issues that would have to be addressed to strengthen environmental regulations.

Answers

a. Fish eggs used as bait do not have time to be digested. Therefore, they would be relatively harmless to the fish and the angler.

b. Fish that eat fish eggs regularly are exposed to a large amount of toxins. The more they eat, the more they bioaccumulate.

c. The safest time to catch female fish would be when they have just spawned and rid themselves of the toxic load. However, fish flesh sometimes becomes less desirable for food at such a time (it may be softer and have a darker color). If the fish were caught before spawning, while still gravid, the problem might be eliminated. People do not usually eat fish eggs (except for caviar). Fishing at this time could seriously reduce the next year's population of fish.

d. Accept student brainstormed answers and discuss them. Americans depend on toxic chemicals for a variety of things; for instance, the fuel we use to power our vehicles (gasoline) is toxic. Toxic chemicals are components of most paints, plastics, batteries, roofing materials, and pesticides used in farming. They are also used in developing film, dry cleaning, producing paper, making many medical supplies (X-ray film), purifying water for public use, caring for lawns, and a large variety of other things.

Teacher's Note

A recent public health advisory chart that indicates which fish are considered dangerous to eat is located in the activity "Which fish can we eat?" Local information is available wherever fishing licenses are sold.

Activity C: Where do all the toxins go? (External View)

Bioaccumulation is the build-up of chemicals in an organism's body – the longer an organism lives, the more it absorbs. When an older, large lake trout is caught, the concentration of toxins in its body could be a million times that of the original concentrations in the water. *Biomagnification* results when toxins become increasingly concentrated as they pass through the food chain. When a fish feeds on zooplankton, for example, the fish takes up toxins in all of the plankton it eats. In the fish, many of the toxins accumulate in its fatty tissues. When a gull or an eagle feeds on the fish, the bird takes up all of the toxins the fish has accumulated from all the contaminated organisms it has ever eaten. Therefore, the higher up an organism is in the food chain, the greater the amount of toxins it is likely to consume.

Earth Systems Understandings

This activity addresses ESU 2 (stewardship), 3 (science processes), and 4 (interactions).

Materials

Each group will need:
- Copy of Table 1.
- Copy of *human activities and industry* cards (1 page).
- 1 *toxin* card.
- Copy of *food chain cards* (3 pages).
- Copy of *effects of toxin* cards (1 page).
- Scissors.
- Posterboard or butcher paper.
- Glue.

OBJECTIVES

When you have completed this activity, you should be able to describe how bioaccumulation and biomagnification of toxins in the food chain cause health disorders in humans and animals.

PROCEDURE

1. The teacher has prepared cards for the teams. Each of the eight themes (fish, mammals, etc.) is on a different color.

2. Work in groups of three to four people to make a poster. First assemble a reasonable food chain from the cards you have.

3. Each group will be given one toxin card and all of the other cards in order to trace the toxin from its origin to its effects in humans and/or other animals. Table 1 will provide source and effect information on the toxins.

4. Have each group show its food chain poster to the class, and explain the interactions they have linked together.

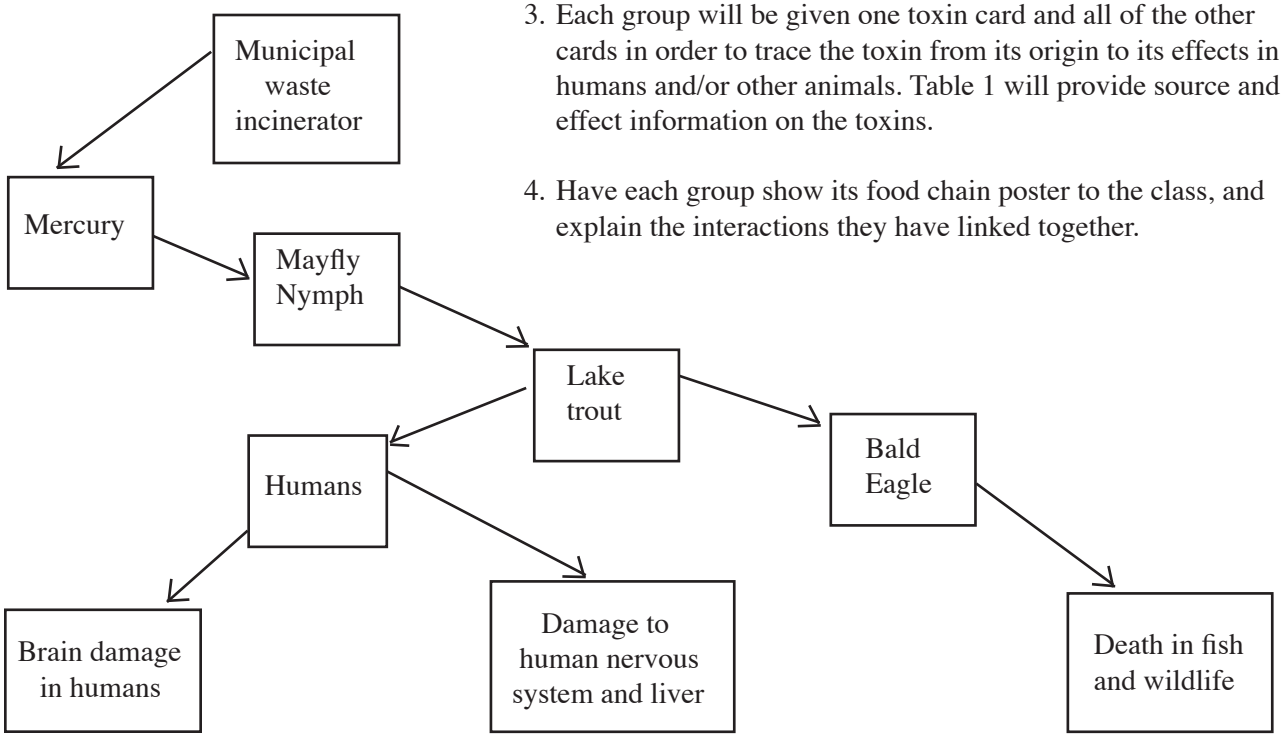


Table 1. Toxins Source and Effect Information.

Name of Toxin	Uses	Source of Toxin	Effects of Toxin
Lead	Used in gasoline, paints, glazes, pipes, and roofing materials	Burning leaded fuels, incinerator emissions, boilers	Toxic effects on humans, fish and wildlife; can cause brain damage
Arsenic	Used in pesticides, smelters, glass production	Pesticide use, coal combustion, primary copper smelters	Poisonous to humans, fish and wildlife
Mercury	Used in batteries, paints, industrial instruments, and pulp and paper mills	Natural, coal combustion, municipal waste incineration, copper smelting, sewage incineration	Affects the nervous system and permanent damage can result; the brain may also be damaged
Benzopyrene (BaP)	Not used alone but is found as a by-product of burning fossil fuels	Combustion processes, such as wood burning, cigarette smoke, and coke oven emissions	Believed to be cause of high incidence of tumors in fish; carcinogen
Hexachlorobenzene	Used to control insects	Pesticide use, manufacture of chlorinated solvents	Linked to nerve and liver damage; suspected to cause birth defects
Additional Airborne Toxins No Longer Produced in the USA:			
PCBs	Once used in industrial products-paints, plastics, electrical transformers	Existing landfills, spills, leaking transformers	Illness develops in humans; fatally toxic to fish and wildlife
DDT, dieldrin	To control insects, fungus, rodents, and weeds	Banned in USA, but still used in Mexico, Central and South America	Will accumulate in humans, fish and wildlife; can cause cancer in humans; toxic to fish and wildlife
Toxaphene	Pesticide used on cotton crops	Was used in southern states, including Texas, Georgia, Alabama and Louisiana	Extremely toxic to fish
Dioxin	Not used alone but is found as a by-product of manufacturing herbicides	Improper incineration of herbicides and leaching from land disposal	Human illness, livestock mortality, extremely toxic

Sources: *Hilleman, 1988; EPA, 1987*

REVIEW QUESTIONS

1. With the use of the constructed food chain, explain what bioaccumulation and magnification are and how these factors cause health disorders in humans and animals.
2. List and explain different types of human activities that produce airborne toxins and what effects these toxins have on humans and animals.

EXTENSIONS

1. Look up information on the percentages of toxins found in the Great Lakes that probably reached there on air currents. Use your maps to determine where these toxins may be originating.
2. Do a study on how incinerators work and how they are regulated.
3. Choose a city and discuss the human health effects that might be found in its residents as a result of the airborne pollutants.

Answers to Review Questions

1. Varies by choice of toxin.
2. Refer to Chart 1 in Activity A of this section and Table 1 of Activity C, which is on this page.

Teacher's Note

A public health advisory chart, which indicates the fish that are considered dangerous to eat, is included with the activity "Which fish can we eat?" These restrictions are a reflection of the bioaccumulation of toxins in those fish.

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Toxins	*Toxins*
DDT	**PCBs**
Dioxins	**Toxaphene**
Mercury	**Lead**
Arsenic	**Benzopyrene**
Hexachloro-benzene	**Dieldrin**
Effects of Toxins	
Human Cancers	**Brain Damage in Humans**

Effects of Toxins	**Tumors in Fish**	**Birth Defects in Humans**
Effects of Toxins	**Death in Fish and Wildlife**	**Damage to Human Nervous System & Liver**
Effects of Toxins	**Human Illness**	**Livestock Mortality**
Plants & Phytoplankton	**Cattails**	**Blue-Green Algae**
Plants & Phytoplankton	**Water Lilies**	**Duckweed**
Plants & Phytoplankton	**Rice Cutgrass**	**Purple Loosestrife**

Food Chain: Birds	**Mallard Duck**	**Bald Eagle**
Food Chain: Birds	**Seagull**	**Blue Heron**
Food Chain: Birds	**Red-Tailed Hawk**	**Blue-Winged Teal Duck**
Food Chain: Fish	**Lake Trout**	**Yellow Perch**
Food Chain: Fish	**Coho Salmon**	**Walleye**
Food Chain: Fish	**Catfish**	**Alewives**

Food Chain: Mollusks, Insect Larvae and Zooplankton	**Caddisfly**	**Snails**
Food Chain: Mollusks, Insect Larvae and Zooplankton	**Zebra Mussels**	**Daphnia (Zooplankton)**
Food Chain: Mollusks, Insect Larvae and Zooplankton	**Mayfly Nymph**	**Freshwater Clams**
Food Chain: Mammals	**Mice**	**Beaver**
Food Chain: Mammals	**Red Fox**	**Raccoon**
Food Chain: Mammals	**Rabbit**	**Muskrat**

Food Chain: Mammals **Human**	
Human Activity & Industries **Incinerators and Boilers**	**Copper Smelters**
Human Activity & Industries **Sewage Incineration**	**Manufacture of Chlorinated Sol-**
Human Activity & Industries **Pulp and Paper Mills**	**Production of Glass**
Human Activity & Industries **Cigarette Smoking**	**Use of Leaded Fuels**
Human Activity & Industries **Application of Agricultural Pesticides**	**Coal Combustion**