HIGH SCHOOL ACTIVITIES

Household Information

Mercury in the Environment

Mercury in Our World and Community

The content in this section was adapted from "Mercury in Schools and the Community: A National Issue." University of Wisconsin System Board of Regents, March 2002.

Region 7

Activity 1 – Mercury I.Q.

Handout to students to test their mercury I.Q.

1. What is mercury?
    a. A type of tree found in the rainforest
    b. An element on the periodic table (symbol: Hg)
    c. A liquid aliens like to put on their hamburgers

2. What is another common name for mercury?
    a. Quicksilver
    b. Space goo
    c. There are no other names for mercury

3. What can mercury be found in?
    a. Switches
    b. Thermostats
    c. Thermometers
    d. All of the above

4. Which animals are most likely to have elevated mercury levels in tissues?
    a. Large fish
    b. Snakes
    c. Birds that live in a rainforest

5. Mercury is used in:
    a. Dental fillings for cavities
    b. Fluorescent lamps
    c. Cars
    d. All of the above

6. Mercury is mined today in what countries? (Mark all that apply)
    a. U.S.
    b. Spain
    c. Mexico
    d. Russia

7. Some states or local governments have passed bans on the sales of:
    a. Mercury thermostats
    b. Mercury thermometers
    c. Fluorescent lights
    d. (a) and (b) above

8. Mercury is the only known metal that is liquid at 72 degrees: True or False

9. Mercury can be very dangerous: True or False

Answer Sheet for activity 1

1. b
2. a
3. d
4. a
5. d
6. b
7. d
8. True
9. True

Activity 2 - Trade-offs

Purpose

One way to reduce mercury pollution from coal burning electrical plants is to use less electricity. Fluorescent light bulbs use much less energy than incandescent light bulbs, but most fluorescent bulbs contain tiny amounts of mercury. What makes sense ecologically?

Objective

Evaluate the pros and cons of two alternative technologies.

Learn how to organize data and determine the mathematical relationships needed to solve a problem.

Coherently present the results of calculations to support a recommended choice or alternative.

Materials

- ✓ Handout titled “Trade-Offs: Your Lights, Your Environment and your Checkbook”
- ✓ Trade-offs: Question sheet and Answer sheet

Procedure

- This activity can be done as homework, or as an individual or group assignment.
- Make copies and distribute “Trade-Offs: Your Lights, Your Environment and Your Checkbook,” and the “Questions” sheet to the students and ask them to prepare answers and justifications for all questions.

Vs.

Fluorescent Bulbs (Containing mercury)

Incandescent bulb

Trade-offs

"Trade-Offs: Your Lights, Your Environment and Your Checkbook" Incandescent vs. Compact Fluorescent Bulbs- Energy Use, Mercury Emissions and Cost

The largest source of mercury to the environment is coal-burning electric power plants. There is a very small amount of mercury in the coal that is burned to produce electricity. However, because vast amounts of coal are burned, the amount of mercury released up the smokestacks is very significant.

One of the largest uses of the electricity produced by these power plants is for lighting homes, buildings and streets. Can the choice of light bulbs in our homes make a difference in terms of the amount of electricity used, the amount of mercury released and the amount that we pay for electricity? Let's figure it out.

	Incandescent Bulb	Compact Fluorescent Bulb
Energy Requirement	60 watts	15 watts
Light Output	870 lumens	925 lumens
Average Life	1,000 hours	10,000 hours
Purchase Price	$1.79 for 4 bulbs	$2.75 each

Cost of electricity from the power plant: $0.07 per kilowatt-hour
Pounds of mercury released per kilowatt-hour of energy used:
3.69E-08 (0.0000000369)

Keep in Mind:

1 kilowatt =1,000 watts
A lumen is a measure of brightness
A kilowatt-hour is a measure of total energy used over a period of time
1 pound = 454 grams
It takes 10 Incandescent bulbs to last as long as 1 compact fluorescent bulb

Equations to Use:

1. Efficiency = light output ÷ energy requirement

2. Amount of mercury released = hours of use x energy requirement x pounds of mercury released per kilowatt-hour of energy x 454 grams/pound of mercury ÷ 1000 watts/kilowatt

3. Electricity cost = Hours of use x energy requirement x cost of electricity ÷1000 watts/kilowatt

Trade-offs

Questions

1. Which type of light bulb - incandescent or compact fluorescent - is more efficient? Why?
2. After 10,000 hours of use, how much mercury (in grams) is released to the environment from the use of each of these two types of light bulbs?
3. After 10,000 hours of use, what are the total costs, including purchase price and electricity, for each type of light bulb?
4. Which type of bulb would you recommend? Why?

Optional

5. Make an educated guess as to how many light bulbs are in use in your community. Based on this estimate, design a study to determine the differences in cost and in mercury released if all those bulbs were either incandescent or compact fluorescent.

Trade-offs

Answers

Which type of light bulb - incandescent or compact fluorescent - is more efficient? Why?

Efficiency, in this case, is measured by light output per amount of energy used. For the compact fluorescent bulb, this is 925 lumens/15 watts = 61.67. For the incandescent bulb, this is 870 lumens/60 watts = 14.5. Thus, the fluorescent bulb is 4.25 times more efficient.

After 10,000 hours of use, how much mercury is released to the environment due to use of each of these two types of bulbs?

The amount of mercury released from use of the compact fluorescent bulb is

> 10,000 hours X 15 watts X .0000000369 pounds per kilowatt-hour X 454 grams per pound ÷ 1,000 watts per kilowatt = .0025 grams.

The equation for the incandescent bulb is the same, except that 60 watts is substituted for 15 watts. Thus, the amount of mercury released is 4 times greater for the incandescent bulb, or .01 grams.

Note: A compact fluorescent bulb contains approximately 4mg (0.004g) of mercury, which is also released to the environment if the bulb is not properly recycled.

After 10,000 hours of use, what are the total costs, including purchase price and electricity, for each type of light bulb?

Purchase price-

Compact fluorescent - $2.75

Incandescent - $1.79/4 X 10,000/1,000 = $4.48

Electricity cost-

Compact fluorescent

10,000 hours X 15 watts X $.07 per kilowatt-hour ÷ 1,000 watts per kilowatt = $10.50

Incandescent

10,000 hours X 60 watts X $.07 per kilowatt-hour ÷ 1,000 watts per kilowatt = $42.00

Total cost-

Compact fluorescent

$2.75 (purchase) + $10.50 (electricity) = $13.25

Incandescent

$4.48 (purchase) + $42.00 (electricity) = $46.48

Thus, the incandescent bulb is three and a half times more expensive.

Which type of bulb would you recommend?

Consider efficiency (compact fluorescent is 4.25 times more efficient), amount of mercury released (4 times less for compact fluorescent if the compact fluorescent bulb is properly recycled) and total cost (three and a half times less for compact fluorescent).

Study design to determine the differences in cost and in mercury released for the community if all those bulbs were either incandescent or compact fluorescent**.**

The study design should include identification of the following steps:

- estimates of the number of bulbs used in lighting homes, streets and businesses
- assumptions about the frequency of bulb replacement
- determination of the total amount of energy used by bulbs in the community
- application of the mercury released per kilowatt factor to determine total mercury releases
- determination of purchase and electricity costs

Mercury in the Environment

In this section, you will learn about the behavior of mercury in the environment and why, in addition to human health concerns relating to direct exposure, mercury is an important environmental issue. Much of the material in this lesson is from the U.S. Environmental Protection Agency's mercury Web site.

Mercury is a silvery, liquid metal at room temperature and is often referred to as one of the "heavy metals." Like water, mercury can evaporate and become airborne. Because it is an element, mercury does not break down into less toxic substances. Once mercury escapes to the environment, it circulates in and out of the atmosphere until it ends up in the bottoms of lakes and oceans. Mercury can be found as the elemental metal or in a wide variety of organic and inorganic compounds. Depending on its chemical form, mercury can travel long distances before it falls to earth with precipitation or dust.

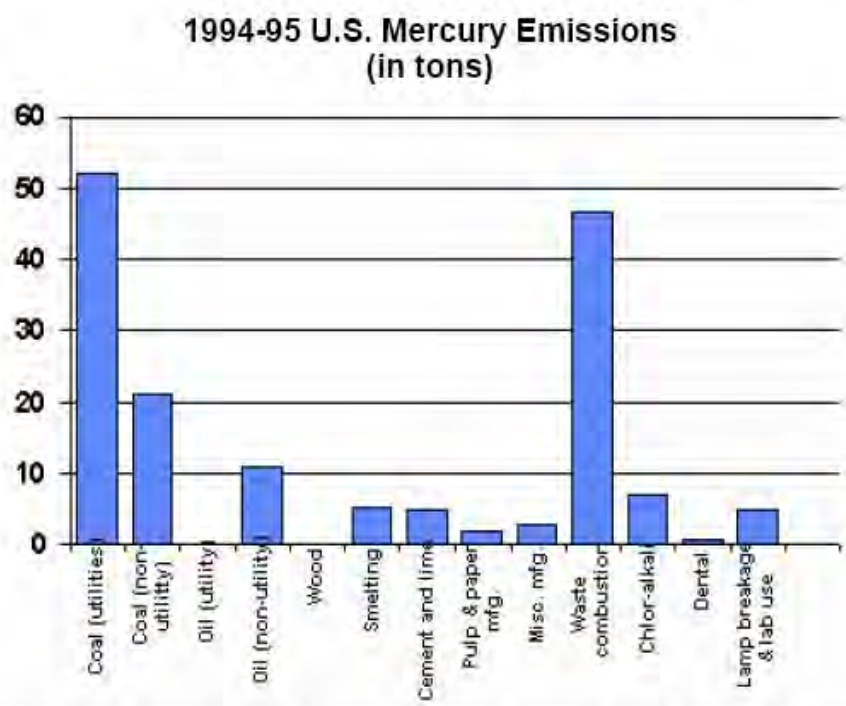
Bacteria and chemical reactions in lakes and wetlands can change the mercury into a much more toxic form known as methylmercury. Fish become contaminated with methylmercury by eating food (plankton and smaller fish) that has absorbed methylmercury.

As long as the fish continue to be exposed to mercury, mercury continually builds up in fish's bodies. Fish that eat other fish become even more highly contaminated. Thus, the largest tend to be the most contaminated.

When people eat the contaminated fish, the methylmercury can remain in their bodies for a long time. If they eat fish containing methylmercury faster than their bodies can discharge it, the methylmercury accumulates in their bodies and can be toxic. Many states have fish consumption advisories to inform people about how many meals of certain types of fish they can safely eat over a period of time.

Where Does Mercury Come From?
Mercury is a naturally occurring element. Mercury ore - cinnabar – is mined in Spain, Algeria, Kyrgyzstan and China. Mercury is also a byproduct of gold and zinc mining. Mercury enters the environment from:

- Natural sources such as volcanoes and the weathering of rocks;
- Our intentional uses of mercury;
- Our unintentional releases of mercury from burning fossil fuels and smelting metals.



(Taken from data in the U.S. Environmental Protection Agency's Mercury Study Report to Congress, 1997.)

Mercury's Environmental Effects

Fish are the main source of food for many birds and other animals, and mercury can seriously damage the health of these species. Loons, eagles, panthers, otters, mink, kingfishers and ospreys eat large quantities of fish. The dose of mercury that these animals ingest through fish can affect the speed and coordination necessary to catch their prey.

Recent research in Minnesota indicates that the following environmental effects are occurring:

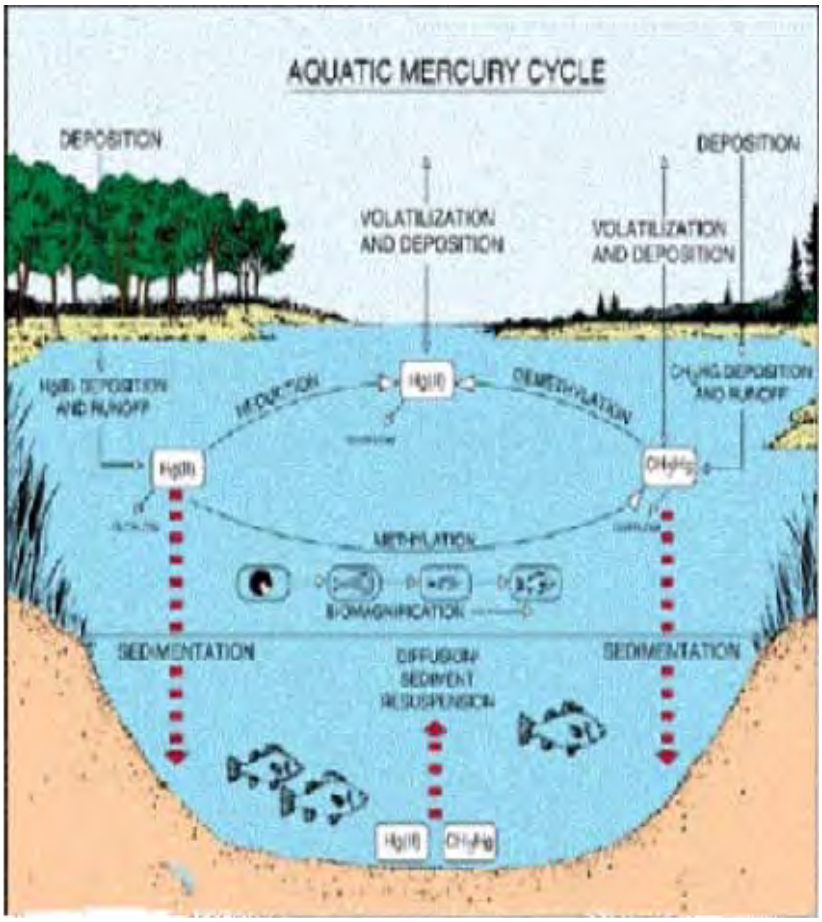
- Loons are accumulating so much mercury that it might be affecting their ability to reproduce;
- Elevated levels of mercury have been found in mink and otters;
- Walleye reproduction might be impaired by the fish's exposure to mercury.

Similar effects are being documented for other fish and fish-eating species around the United States and Canada. Has there always been mercury contamination, or is this a recent problem? This is a difficult question to answer, in part because of a lack of adequately preserved fish specimens of pre-industrial age to compare against contemporary samples. However, several lines of evidence from recent studies on Wisconsin lakes suggest that increased emissions to the atmosphere, and subsequent higher deposition rates to lakes, likely translate into higher mercury levels in fish.

The Mercury Cycle and Bioaccumulation

There is a constant **biogeochemical cycle** of mercury. This cycle includes

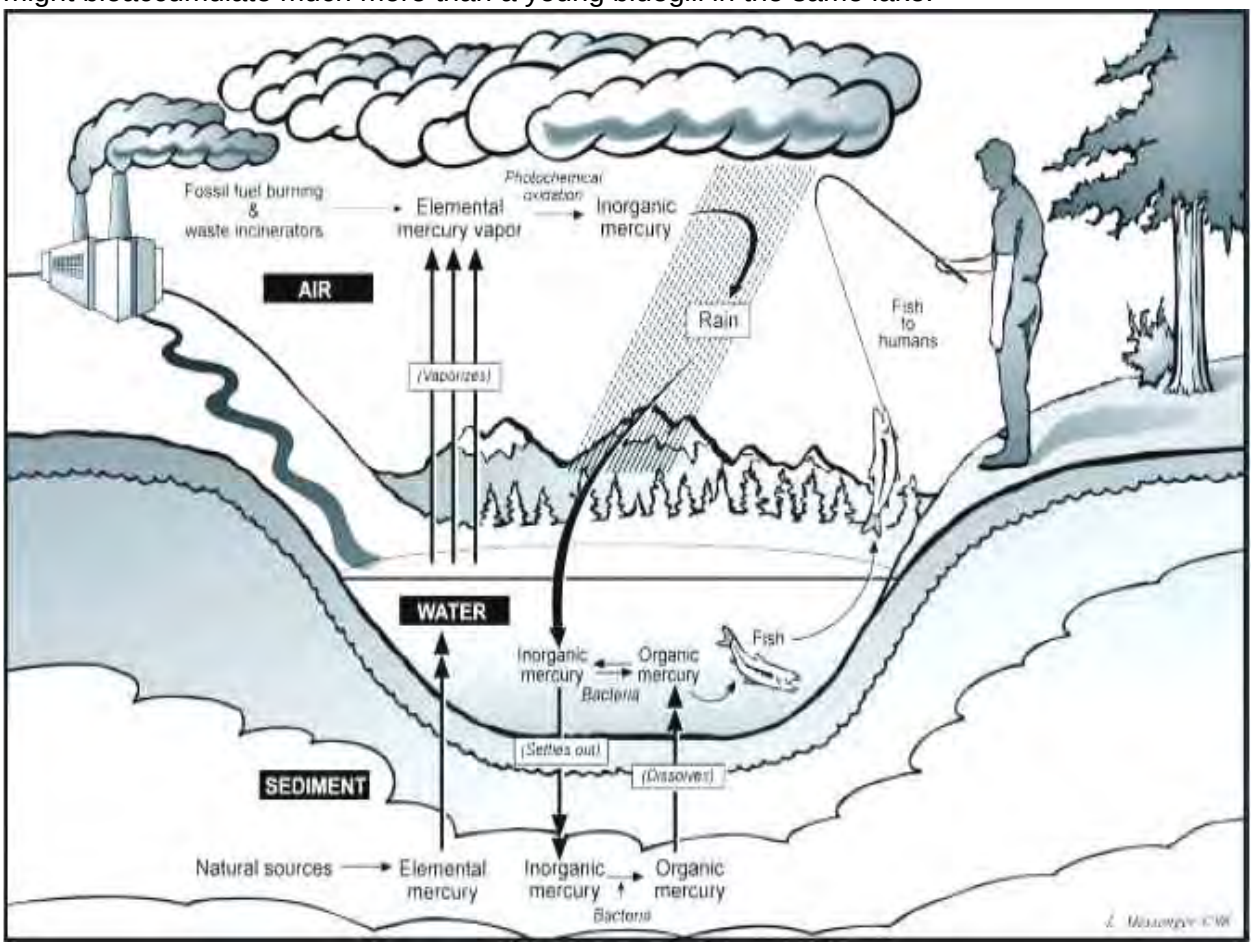
- release of elemental mercury as a gas from the rocks and waters (degassing);
- long-range transport of the gases in the atmosphere;
- wet and dry deposition upon land and surface water;
- absorption onto sediment particles;
- bioaccumulation (or biomagnification) in terrestrial and aquatic food chains.



Bioaccumulation means an increase in the concentration of a chemical in an organism over time, compared to the chemical's concentration in the environment. Bioaccumulation can be a normal and essential process for the growth of any species, but the accumulation of unnecessary chemicals or toxins, or even the overaccumulation of essential substances can be detrimental. All animals, including humans, daily bioaccumulate many vital nutrients, such as vitamins A, D, and K, trace minerals, essential fats and amino acids, but unfortunately, they can also accumulate many unnecessary substances, such as lead or mercury. What concerns toxicologists is the bioaccumulation of necessary substances to levels in the body that can cause harm. With substances such as lead or mercury, any accumulation at all can be harmful. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

Understanding the dynamic process of bioaccumulation is important in protecting humans and other organisms from the adverse effects of chemical exposure, and it has become a critical consideration in the regulation of chemicals.

Bioaccumulation varies among individual organisms as well as among species.
Large, fat, long-lived individuals or species with low rates of metabolism or excretion of a chemical will bioaccumulate more than small, thin, short-lived organisms. Thus, an old lake trout might bioaccumulate much more than a young bluegill in the same lake.



Above is a schematic drawing of mercury cycling in an aquatic ecosystem. With the exception of isolated cases of known point sources, the source of most mercury to most aquatic ecosystems is deposition from the atmosphere, primarily associated with rainfall.

In the aquatic environment, mercury can be

- dissolved or suspended in the water
- trapped in the sediments
- ingested by living things (biota)

Methylmercury is the form of mercury most available and most toxic to biota (including zooplankton, insects, fish, and humans). This form of mercury is easily taken up by biota and bioaccumulates in their tissues. Unlike many other fish contaminants, such as PCBs, dioxin, and DDT, mercury does not concentrate in the fat but throughout the muscle tissue. Thus, there is no simple way to remove mercury-contaminated portions from fish that is to be eaten.

Activity 3 - Mercury in the Food Chain

Purpose
This activity will help the students reinforce their understanding of food webs while gaining a new understanding of bioaccumulation.

Objectives:
Students will
1) Display a graphic understanding of an aquatic food web for a specific local body of water; and
2) Demonstrate an understanding of bioaccumulation.

Materials:
- ✓ A map of your state showing waterways (a state highway map will usually work), paper and something to draw with
- ✓ Copies of "Example from Florida aquatic food web and mercury cycle" and information provided in ***Mercury in the Environment*** section of this curriculum package
- ✓ If you choose the teacher lead option you will need the following materials:
  - 10 very small (1-2 oz.) cups
  - (clear containers are the best, but use what you have).
  - 5 small containers (4 –5 oz.)
  - 3 medium containers (around 8 oz.)
  - 1 clear container (large to hold around 7-8 cups)
  - Glitter (3 colors) or small beads (3 colors) or something similar that is very small and can be found in 3 distinct colors

Procedure:

1. Select a body of water or a number of water systems in your state.
2. Divide the class into study groups. Assign each group a lake, river, bay, coastal area, etc. Each group should then create a food web for their study site. Include as many of the components that they can find. You may use the Florida example on page 14 as an idea sheet.
3. Select either student self-discovery or teacher lead and follow accordingly.
4. Students should share their findings.

Select one of the two options: student self-discovery or teacher lead

Student self-discovery: Present each group the following scenario – the water they are in charge of has shown signs of mercury contamination. As scientists they are to demonstrate to the public what "bioaccumulation" is and why we have to be concerned about it.

1. Allow them to use a variety of materials.
2. Give each group 5 minutes for their demonstration.
3. If you wish, you can set up a town board to judge who did the best job of demonstrating the issue.

Teacher lead:

You will need to gather the following materials: (clear containers are the best, but use what you have).

- 10 very small cups (1-2 oz.)
- 5 small containers (4 –5 oz.)
- 3 medium containers (around 8 oz.)
- 1 clear container (large to hold around 7-8 cups)
- Glitter (3 colors) or small beads (3 colors) or something similar that is very small and can be found in 3 distinct colors.

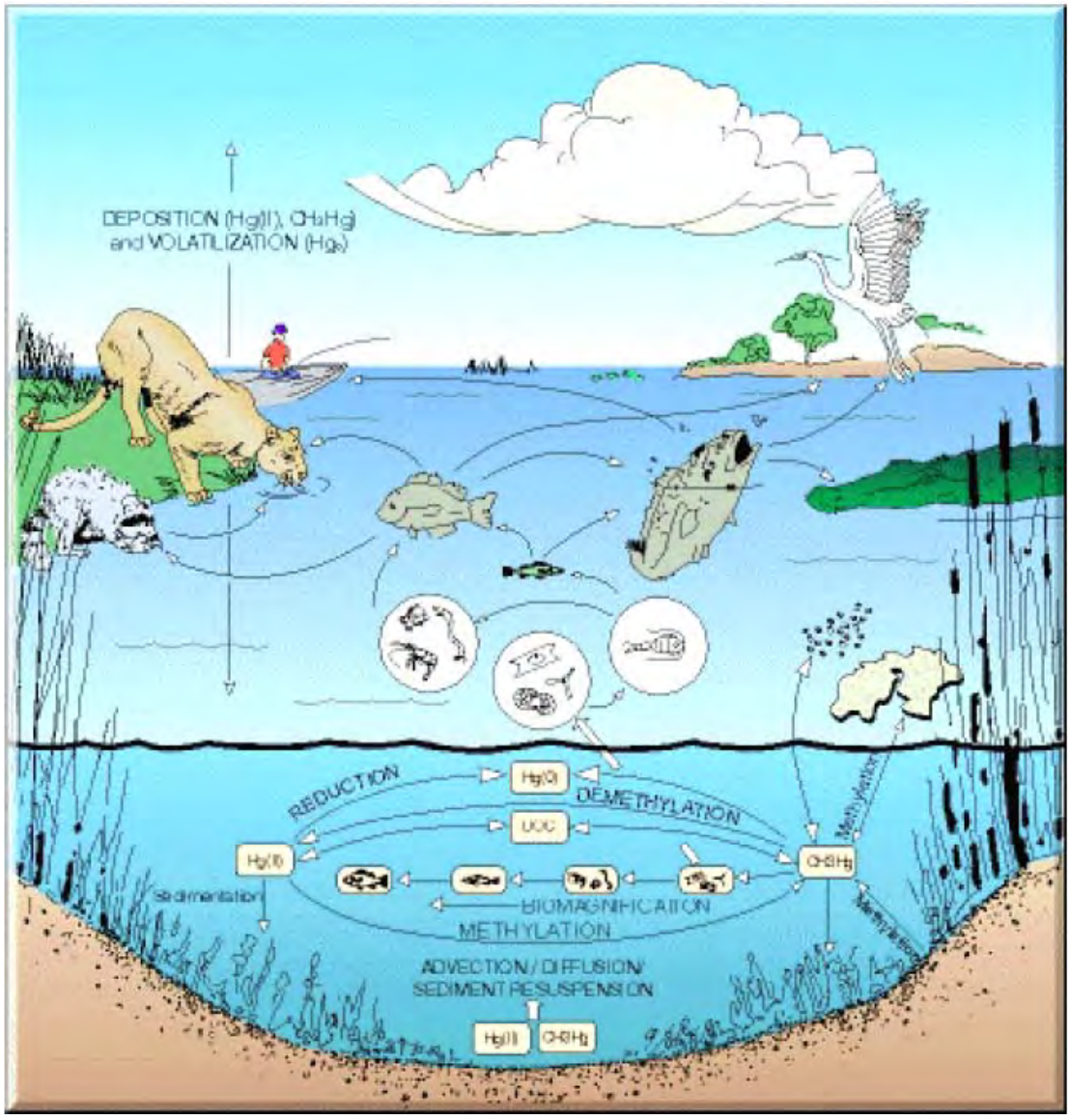
1. Fill each container to one-third full with water.
2. Now, representing mercury, you will put a pinch of one color of glitter in each of the 10 very small (1-2 oz.), another color in the 5 small containers (4 –5 oz.), and the third color in the 3 medium containers (8 oz.)

Using one of the food chains the students developed, have the students label the 10 very small ones as the micro-organisms, the 5 small ones as the animal that eats the microorganisms (small fish, insects, etc.), the medium would be the animal that eats the small ones and the clear container will represent a top predator.

Now have the students help you with the demonstration and put the food chain and bioaccumulation into action. First, the 10 very small containers (they are being eaten by the primary consumer) are poured into the small containers. Some of the glitter might stay in each container as you pour. That is OK; it represents the mercury that is excreted by the animal (not 100 percent of the mercury accumulates). Now the small containers will be eaten by the medium or secondary consumer. And finally the medium are eaten by the top predator (tertiary consumer).

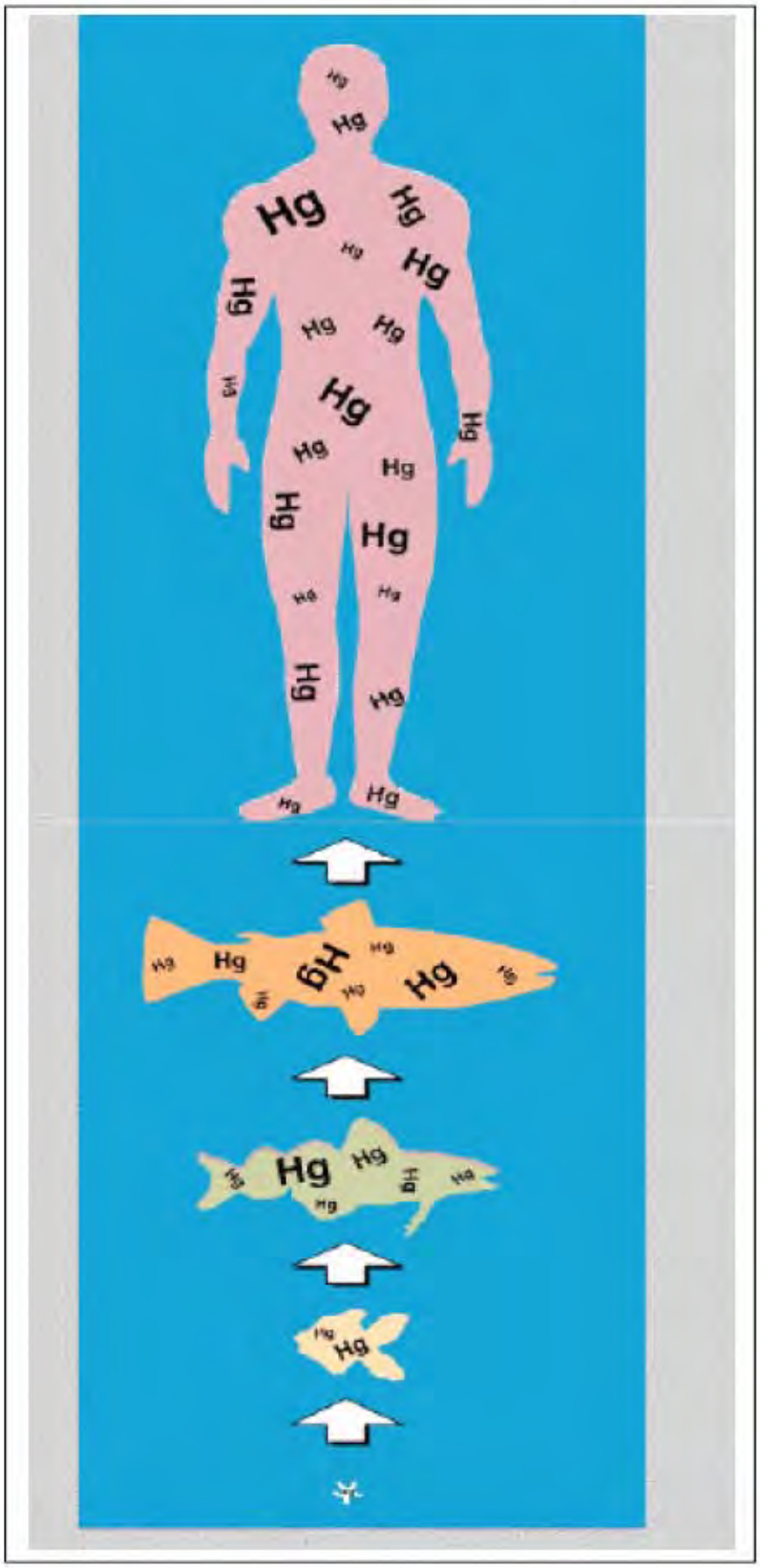
Discuss what just happened, with special emphasis on the glitter. How much of the mercury was accumulated by the top predator?

Regardless of whether you did the student self-discovery or the teacher lead option, now hand out the **Bioaccumlation in humans** chart on page 15 and discuss what they have learned through the activity.



Example from Florida aquatic food web and mercury cycle

Bioaccumlation in humans



Activity 4 – Atmospheric Mercury

The majority of mercury entering lakes, streams, rivers, and oceans comes from the atmosphere. It is important to understand why mercury is in the atmosphere because once we understand the causes, we can concentrate on controlling the sources. In this activity, students will begin to recognize patterns and make educated guesses based on those patterns.

Objective

1. Students will demonstrate critical thinking skills.
2. Students will make educated guesses (scientific inquiry) based on patterns shown in data.

Materials

- ✓ *Mercury Sources Fact Sheet*
- ✓ Activity 7 sheets: First, *Where is Mercury?*; Second, *Mercury in the Air*; Third, *Fish Advisories*
- ✓ Background information concerning fish advisories…
- ✓ Optional: EPA Fact Sheet

Procedure

1. This activity is based on critical thinking and the development of the thought process; therefore, it is crucial that the different parts are given one at a time, in the prescribed order. The activity can be done individually, in small groups, or as a large group in a discussion format.
2. Hand out the pages, *Mercury Sources Fact Sheet* (p. 17) and *Where is Mercury?* (p. 18). Have students review data and complete the assignment.
3. Once the first assignment is complete, hand out *Mercury in the Air* (p. 19). They will need their first assignment to complete the second.
4. Once the second assignment is complete, hand out the third, *Fish Advisories* (pp. 20-23). They will need the first and second to complete the third.

Optional

5. Review and discuss the EPA fact sheet (which can be found at the end of this activity on p. 24).

Mercury Sources Fact Sheet

Coal Plants are Largest Mercury Source

The majority of mercury entering lakes, streams, rivers, and oceans comes from the atmosphere. Air deposition accounts for up to 90 percent of the mercury entering Lake Superior, and 80 percent entering the Delaware Bay.

- 85 percent of mercury emissions come from smokestacks, primarily power plants and municipal and medical waste incinerators.
- 33 percent of all mercury emissions come from power plants (coal- and oil-fired), emitting 52 tons per year.

How Far does Mercury Travel in the Atmosphere?

The amount of mercury deposited around a smokestack depends on the height of the stack, the chemical species of the mercury, and the amount of rainfall at the particular site. Using power plants as an example, the table below shows that plants with shorter stacks will have more local deposition than those with taller stacks, and more mercury is deposited locally in a humid site compared to an arid site.

EPA models estimate that 7 percent to 45 percent of all mercury emitted in humid sites deposits within a 30-mile radius, whereas 2 percent to 38 percent emitted in arid sites deposits within 30 miles. This implies that at least 55 percent of all mercury emissions are transported more than 30 miles from the source, and models show that mercury can be transported across considerable distances.

The Electric Power Research Institute calculates that up to 10 percent of the mercury released deposits within 62 miles of a power plant, and the rest is transported regionally and globally.

Power Plant Type	Average Stack Height (ft)	Percent of Emissions Deposited within 30 miles	
		Arid Site	**Humid Site**
Large coal-fired power plant	731	2	7
Medium coal-fired power plant	465	4	9
Oil-fired power plant	288	6	11
Small coal-fired power plant	265	9	14

Source: US EPA, 1997, *Mercury Study Report to Congress—Volume III*, Tables 5-15 and 5-16. Note: The percent deposited at each site is the sum of the percent deposited via dry deposition and wet deposition.

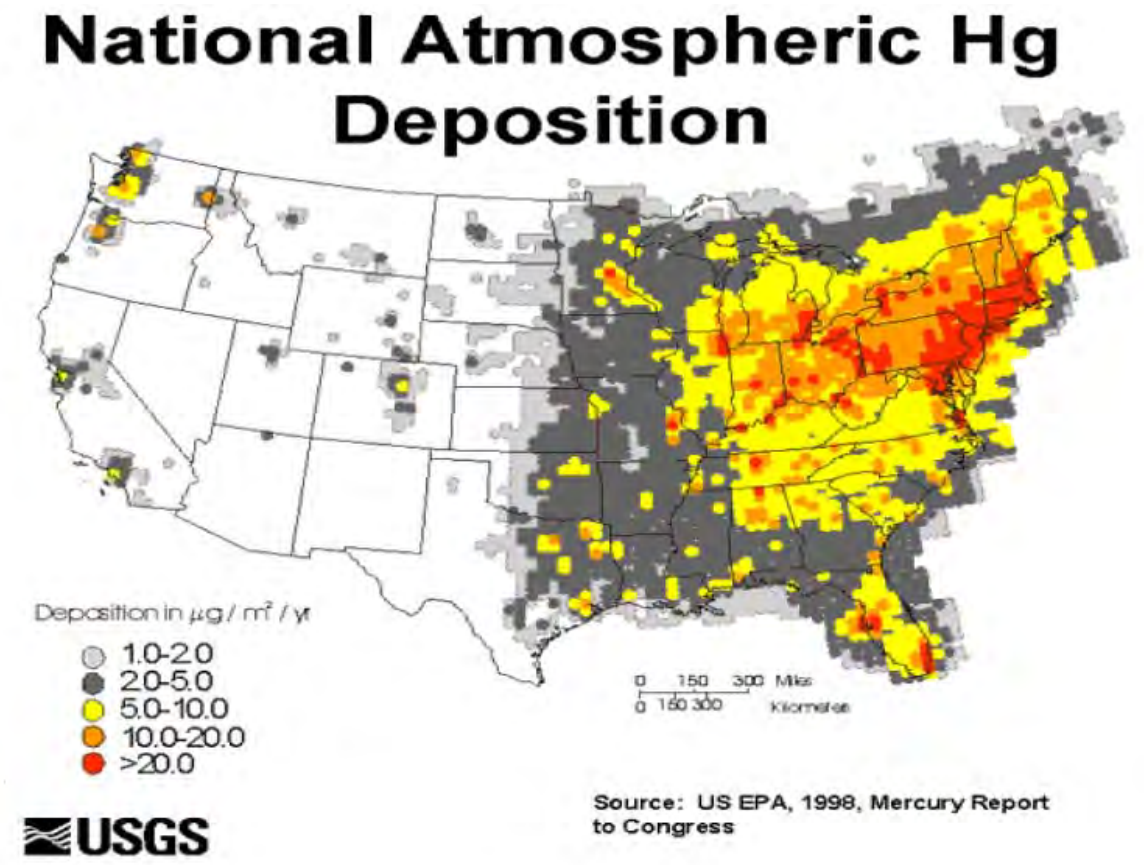
Activity 4 – *Where is Mercury?*

Which state(s) do you think have the biggest problem with atmospheric mercury (mercury that travels through the air)?
Keep in mind:

- Areas of large populations of people using electrical energy.
- General wind patterns travel from west to east.

Highlight on map where you think the biggest atmospheric mercury problem would be and explain why.

Activity 4 – *Mercury in the Air*



How would you explain the pattern shown on this map?
(What are the similarities and differences?)

After reviewing this map, would you be more concerned about mercury if you lived in New York, Texas, or California? Does this mean the other two (that you didn't pick) do not have to worry about mercury?

Activity 4 – *Fish Advisories*

How does the National Atmospheric Hg Deposition map relate to this map?
(Are there similarities or patterns between the two?)

Why would a state such as New Mexico, which does not show any atmospheric mercury deposition, have as high or higher amounts of fish advisories than a state that is in the middle of the heavy atmospheric deposition (such as West Virginia)?

Background information concerning differences in fish advisories and atmospheric deposition in New Mexico and West Virginia

The following information shows that even though West Virginia is in the area of much higher mercury deposition, New Mexico has been able to do more extensive research and is taking a more preventative stand than most states.

Excerpt taken from a release from the West Virginia Bureau for Public Health:

The West Virginia Bureau for Public Health (BPH) encourages anglers and consumers to take notice of advisory notifications issued warning pregnant women, women of child bearing age, nursing mothers and children about the health concerns of consuming fish that may be contaminated with mercury. The warnings were issued by the United States Environmental Protection Agency and the Food and Drug Administration.

This action is being taken based on an assessment by U.S. Environmental Protection Agency (EPA) of data collected nationwide. The agencies in West Virginia that develop fish consumption advisories, the Bureau for Public Health, Division of Natural Resources and Department of Environmental Protection, agree that limited data currently available in West Virginia support this recommendation, however, additional fish sampling is required to determine more specifically the extent, level of contamination and species affected by mercury.

A short summary of New Mexico's efforts:
(taken from New Mexico Environment Department)
Atmospheric deposition of mercury
With the exception of localized mineral deposits and certain industrial settings, the greatest source of mercury to the environment is atmospheric deposition. Even though the concentration in the atmosphere is very low, our watersheds provide large catchments, and mercury is carried by runoff into waterways on fine particles of soil. These particles, easily held in suspension by the force of moving water, are eventually trapped behind dams, where they settle into the poorly oxygenated region at the bottom of the reservoir. In the anoxic sediments and hypolimnetic waters above them, sulfate reducing bacteria combine some of the inorganic mercury with methane, forming the methylmercury that biomagnifies so powerfully as it is concentrated and passed from prey to predator up the food chain.

Because mercury has been found in some fish at concentrations which could lead to significant adverse human health effects, specific guidelines have been prepared These guidelines allow those who fish and their families to make an informed decision as to what fish they can safely eat. While the occasional consumer of fish from these waters is at little risk if they are otherwise in good health, ingestion of mercury at levels found in some fish over a long period of time could result in health problems such as kidney disease and/or eye, respiratory tract, nervous system or brain damage.

How did we first discover the problem?
Some routine spot-checking by the federal government first found the problem. We verified it, and continued testing other lakes in New Mexico.

Have enough fish been tested to be really sure of the level of mercury contamination?
Yes, for the lakes for which we have issued health advisories. Mercury levels are strongly correlated with the length of the fish because longer fish are older and have had more time to accumulate mercury. Thus only four fish of different lengths from each species in a lake need to be tested in order to predict with great accuracy the levels of mercury in all the fish. However, we are testing more fish than this in order to verify our statistical models.

Where is the mercury in the fish coming from?
We don't know for sure, but we have not found any single source for it here in New Mexico so far. Studies in other areas of the U.S. and the world have found that most of the mercury appears to be coming from the air and then deposits in lakes and on soil. The mercury gets into the air from industrial processes including smelters. Another possibility is that mercury can be found naturally in different types of soils, and become washed into lakes with soil disturbances such as overgrazing, housing developments, road developments, etc.

Why would some lakes have a problem and others not?
The factors which affect the amount of mercury which gets into the fish are not fully understood. However, some of them appear to be:

1. More acid lakes lead to more conversion of mercury to methylmercury, which is taken up by the fish more easily.
2. Recently formed lakes, especially those with submerged decaying vegetation such as trees, are more likely to convert mercury to methylmercury.
3. Smaller lakes may have the mercury more concentrated.
4. Rivers with swiftly moving water will usually have less concentrated mercury.
5. Bigger fish, and species of fish which eat other fish, get larger amounts of mercury.

State/EPA mercury screening survey
In 1995 and 1996, staff of the Surface Water Quality Bureau (SWQB) conducted a screening survey for mercury covering over 2,000 miles of New Mexico's waterways. Analyses were provided, free of charge, by EPA s Environmental Monitoring Systems Laboratory (EMSL) in Cincinnati, Ohio. EMSL was able to provide a minimum detection limit of 0.7 ng/L (0.7 parts per trillion). Using ultra-clean sample handling protocols developed by SWQB staff, over two hundred stations were sampled before the EMSL project lost its funding and was terminated. This study is the most comprehensive evaluation of mercury levels in New Mexico's waters ever conducted. The Surface Water Quality Bureau has been given the use of the analytical equipment used in the State/EMSL mercury screening survey. This equipment now resides at the Scientific Laboratory Division of the New Mexico Department of Health (SLD). Staff of the SLD are currently developing a small clean room to provide a suitable laboratory environment for the analysis of mercury at low parts per trillion levels.

Survey results
The data from that study show that, with some notable exceptions, mercury levels in our rivers and streams are very low. The average concentration of mercury in New Mexico's waters is less than 2.5 ng/L (Range: 0.0 ng/L to 500.0 ng/L). No water sample drawn from any major waterway in New Mexico has been found to contain mercury at a level that could pose any degree of direct risk to humans or wildlife. While much work remains to be done, to date it appears that in all but one instance where mercury was found to exceed the current state chronic criterion of 12 ng/L (parts per trillion) its occurrence can be attributed to either mining activity or storm water runoff from Los Alamos National Laboratories (Up to >3,400 ng/L). The single exception appears to be related to a coal seam in San Juan County.

Fish tissue mercury concentrations
Despite the extremely low concentrations of mercury in the State's waters, levels in the tissues of certain fish, (usually large, predatory species), can still exceed the FDA action limit of 1.0 part per million, an increase over background of six orders of magnitude. It is this tendency of mercury to biomagnify as it is passed up the food chain that generates concern. Fish are about ten times as tolerant of mercury than are humans. This is possible because they have evolved an efficient strategy for sequestering mercury away from vital organs: they store it in muscle tissue - the portion we eat.

United States Environmental Protection Agency
Office of Water 4305
EPA-823-F-01-010 April 2001

EPA Fact Sheet

Update: National Listing of Fish and Wildlife Advisories

Summary

The 2000 ***National Listing of Fish and Wildlife Advisories*** *is now available from the U.S. Environmental Protection Agency (EPA). States, tribes, and territories report that the number of fish consumption advisories issued in 2000 rose by 187, a 7% increase over 1999. The total number of advisories in the United States increased for four major contaminants—mercury, PCBs, dioxins, and DDT—but remained the same for chlordane. This is the third year in which the number of advisories issued for chlordane has declined or remained constant. The increase in advisories generally reflects an increase in the number of assessments performed and the improved quality of monitoring and data collection methods. The number of acres of lakes under advisory increased from 20.4% in 1999 to 23% in 2000, a total of 63,288 lakes, while the number of river miles under advisory increased from 6.8% in 1999 to 9.3% in 2000. The survey showed that 100% of the Great Lakes and their connecting waters and 71% of coastal waters of the contiguous 48 states were under advisory in 2000.*

The national listing is available on the Internet at: http://www.epa.gov/waterscience/fish/

Background

The states, territories, and Native American tribes (hereafter referred to as states) have primary responsibility for protecting residents from the health risks of eating contaminated fish and wildlife. If high concentrations of chemicals, such as mercury or PCBs, are found in local fish and wildlife, then a state may issue a consumption advisory for the general population, including recreational and subsistence fishers, as well as for sensitive subpopulations (such as pregnant women, nursing mothers, and children). A consumption advisory may include recommendations to limit or avoid eating certain fish and wildlife species caught from specific waterbodies or, in some cases, from specific waterbody types (e.g., all lakes). Similarly, in Canada, the provinces and territories have primary responsibility for issuing fish consumption advisories for their residents.

States typically issue five major types of advisories and bans to protect both the general population and specific subpopulations.

- **No-consumption advisory for the general population** – Issued when levels of chemical contamination in fish or wildlife pose a health risk to the general public. The general population is advised to avoid eating certain types of locally caught fish or wildlife.
- **No-consumption advisory for sensitive subpopulations** – Issued when contaminant levels in fish or wildlife pose a health risk to sensitive subpopulations (such as pregnant women and children). Sensitive subpopulations are advised to avoid eating certain types of locally caught fish or wildlife.
- **Restricted consumption advisory for the general population** – Issued when contaminant levels in fish or wildlife may pose a health risk if too much fish or wildlife is consumed. The general population is advised to limit eating certain types of locally caught fish or wildlife.
- **Restricted consumption advisory for sensitive subpopulations** – Issued when contaminant levels in fish or wildlife may pose a health risk if too much fish or wildlife is consumed. Sensitive subpopulations are advised to limit eating certain types of locally caught fish or wildlife.
- **Commercial Fishing Ban** – Issued when high levels of contamination are found in fish caught for commercial purposes. These bans prohibit the commercial harvest and sale of fish, shellfish, and/or wildlife species from a designated waterbody.

As shown in Table 1, advisories of all types increased in number from 1993 to 2000.

Table 1. U.S. Advisories Issued from 1993 to 2000 by Type

	1993	1994	1995	1996	1997	1998	1999	2000
No Consumption – General Population	503	462	463	563	545	532	570	663
No Consumption – Sensitive Subpopulation	555	720	778	1,022	1,119	1,211	1,285	1,417
Restricted Consumption – General Population	993	1,182	1,372	1,763	1,843	2,062	2,213	2,475
Restricted Consumption – Sensitive Subpopulation	689	900	1,042	1,370	1,450	1,595	1,630	1,802
Commercial Fishing Ban	30	30	55	50	52	50	50	51

Mercury In Our World and Community!

To gain a clear understanding of the impact of mercury on our communities and lives, it is good to have an understanding of historical mercury uses and what is happening right now. To do this, this section has been divided into two sections: Mercury through the Ages, which is an excellent way to work on your students' history achievement standards and science at the same time; and Mercury Right Here and Now. There are things you can do today to reduce mercury pollution in our world, giving the youth a sense of immediate success and also helping the community by reducing the possibility of mercury poisoning.

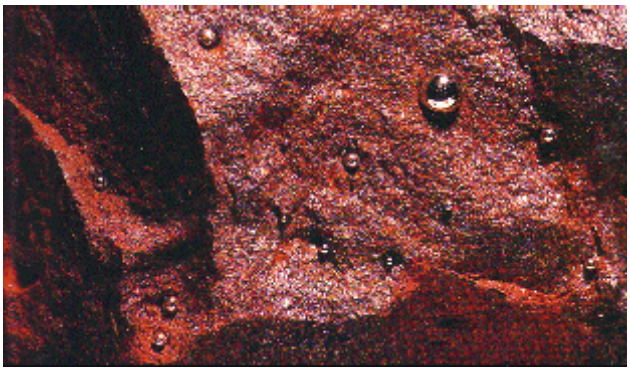
Mercury through the Ages

You will explore the historical uses of mercury, from ancient cultures in Egypt and China to a 1950s American car classic and everything in between. You can contrast these historical uses with the current uses described in previous sections of this curriculum.

The Ancients

Mercury has been known since ancient times. The chemical symbol, Hg, is taken from the Latin, *hydrargyrus*, meaning "liquid silver." Evidence shows that the Chinese were using mercury before 2000 B.C. The ancients realized mercury was toxic and assigned the task of mining quicksilver to slaves and prisoners. The average life span of miners was 3 years from when they started this hazardous work. Ancient Egyptian tombs contain vials of mercury, demonstrating the ability to mine and refine mercury.

Virtually all mercury is derived from *cinnabar*, or mercury sulfide (HgS). Red cinnabar is so rich in mercury content that droplets of elemental mercury can be found in samples of the ore. The ore is heated with a **reducing agent** (such as **oxygen**, **iron**, and quicklime), and the mercury vapor is released into vertical columns of water, where the mercury liquefies. Mercury is quite dense; it collects at the bottom while most impurities float on the surface, where they can be scraped away.



Cinnabar—mercury ore

From the Middle Ages through the Renaissance

Alchemist's text

During the middle ages, alchemists experimented with various ways of turning metals and other substances into gold. Many used mercury in their processes and many were poisoned, although no one knew the cause at the time.

Many of the English monarchs during this period also dabbled in alchemy, and experts suspect that at least some of their erratic behavior can be explained by mercury poisoning! King Charles II, who became king of England in 1660, was a practicing chemist/alchemist who had his own laboratory. He experienced personality changes late in life and died of kidney failure, probably from mercury poisoning.

Historians of science have studied the lives of several famous scientists of the period and conclude that historical accounts of certain years of their lives, which correspond with their use of mercury, exhibit strong evidence of the symptoms of mercury poisoning.

One such notable is Sir Isaac Newton, although historians are quick to point out that the period of suspected mercury poisoning in his life did not occur while he was deriving the calculus or deducing the law of gravitation. Newton also was an alchemist who actually tasted the chemicals he worked with. At age 49, he became emotionally disturbed for a couple of years. In 1979, hair strands from his corpse

were tested for mercury and were found to contain 75 parts per million. (Normal levels are about 5 parts per million.)

Another scientist who worked with mercury and exhibited some erratic behaviors was chemist and physicist Sir Michael Faraday, discoverer of electricity. He used mercury in his electrical equipment and suffered from memory loss and a nervous breakdown.

Mercury in Medicine

Mercury has been used in a variety of medical remedies for a long time. One of its most important uses was for treatment of syphilis. Syphilis was rather widespread among the ruling families of Europe, and mercury was the most prominent treatment for several centuries. Historians speculate that many of these rulers experienced mercury poisoning. The "common man" was also subject to this disease, and the treatment was the same—mercury. The following account illustrates how knowledge of this treatment regime was put to good use in a recent archaeological study.

> Archaeologists seeking the elusive remains of Fort Clatsop, the winter quarters of the Lewis and Clark expedition in 1805-1806, are getting down to basics—they are looking for the camp's privies. Researchers from the National Park Service, the Museum of the Rockies and the University of Washington are analyzing levels of mercury in the soil at the site, near Astoria, Oregon. Mercury was a common Army treatment for syphilis: Meriweather Lewis dispensed it in large doses to the men of the Corps of Discovery.
>
> High levels of the metal in specific soil samples would indicate the site of a privy. "With 33 men there for 106 days, we should be able to find some high concentrations of mercury," said Cindy Orlando, Superintendent of the Fort Clatsop National memorial. Because Army regulations at the time stipulated that privies be located certain distances from encampments, finding signs of one would make it easier to locate the 50-foot by 50-foot fort.

Route of the Lewis and Clark expedition

Mercury was also part of a common anti-depressive medication formulation used during the 19th century. The following article, titled “Lincoln’s Little Blue Pill,” appearing on ABCNews.com on July 17, 2001, shows how users of this medication were probably exchanging one set of symptoms (depression) for another (mercury poisoning). It also illustrates how the effects of mercury are reversible once the exposure is eliminated.

> At one point during a debate, Lincoln reached over and picked up a man by the collar and shook him “until his teeth chattered,” according to a study that appears in the summer issue of Perspectives in Biology and Medicine. He became so angry “his voice thrilled and his whole frame shook,” the study says. Lincoln only stopped when someone, “fearing that he would shake Ficklin’s head off,” broke his grip. The study says mercury poisoning may explain Lincoln’s behavior. “We wondered how a man could be described as having the patience of a saint in his 50s when only a few years earlier he was subject to outbursts of rage and bizarre behavior,” said Dr. Norbert Hirschhorn, a retired public health physician, medical historian and lead author of the study.

Abraham Lincoln during a calmer moment

The study reformulated “blue mass,” a common anti-depressive medication of the 19th century that Lincoln took. The study showed that it would have delivered a daily dose of mercury exceeding the EPA standard by nearly 9,000 times. “Mercury poisoning certainly would explain Lincoln’s known neurological symptoms: insomnia, tremor and rage attacks,” said Dr. Robert G. Feldman, an expert on heavy metal poisoning and co-author of the paper. “But what is even more important, because the behavioral effects of mercury may be reversible, it also explains the composure for which he was famous during his tenure as president.”

The ingredients in “blue mass,” besides mercury, included licorice root, rose water, honey, sugar, and dead rose petals, according to the study. It was compounded with an old-fashioned mortar and pestle and rolled to size on a 19th-century pill tile. The vapor released by two pills in the stomach would have been 40 times the limit set by the U.S. National Institute for Occupational Health, the researchers found. The amount of solid mercury absorbed from two pills would have been 750 micrograms. The EPA indicates that not more than 21 micrograms of any form of mercury per day should be safely ingested. Someone who consumed the common dose of two to three little pills per day would have been at serious risk for mercury poisoning, the study said. Mercury was also used in antiseptic formulations (e.g. mercurochrome) and anti-itching compounds (e.g. calamine lotion).

Industrial Mercury

By the 1800s, mercuric nitrate was widely used to soften fur for hats. The resulting exposure of workers led to a classic syndrome and the phrase "mad as a hatter." In Danbury, Connecticut, a center of hat making, the effects of exposure were characterized as "Danbury Shakes." It was not until 1941 that the use of mercuric nitrate in hat making was banned in most states.

One of the world's best-known mercury mines--the Almaden mine in Spain—has been in continuous operation since 400 B.C. Mercury's discovery in California predates the discovery of gold by several years. The discovery of commercial mercury ore bodies led to the development and operation of numerous mines from the 1840s to the early 1960s, from which more than 220 million pounds of elemental mercury were produced. The 1848 discovery of gold in the Sierra Nevada created a ready market for mercury produced by the mines in California's coastal ranges. Mercury forms a relatively insoluble amalgam with gold, and miners used this property to increase gold recovery. An estimated 10 to 30 percent of the mercury was lost to the environment in this process, transported into streams and reservoirs along with the discharged sediments (tailings or “slickens”) from the hydraulic mining operations. Mercury from hydraulic mining has been transported with sediments downstream into the San Francisco Bay/Sacramento-San Joaquin Delta estuary, where it has probably contributed to elevated mercury concentrations in fish, resulting in consumption advisories.

Mercury in the Twentieth Century

Mercury achieved widespread use during the 1900s in industrial, commercial, and residential applications because of its many unique properties. Many of these uses exist today. Other uses have been banned or phased out; for example, mercury in latex paints, children’s sneakers that lit up and maze games.

One particularly interesting use of mercury that has since been eliminated was in cars. Up to 40 pounds of mercury were incorporated into the road leveling device on one model of late 1950s Studebaker. Who knows what happened to all that mercury and if the vintage Studebaker owners of today are aware of what is in their vehicles. (Other uses of mercury in cars, such as in tilt switches that control trunk lights, have not yet been totally phased out.)

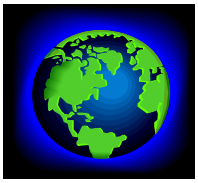
Activity 5 - Mercury through the ages

Using the attached table on page 31, “Unique Properties of Mercury,” and the information in the preceding Mercury though the Ages section, ask the students to complete the following activity.

For each of the following historic uses of mercury, indicate the unique properties of mercury that form the basis for this use and, if time permits, think of or research a non-mercury alternative to that use.

Historic use	unique property(s)	non-mercury alternative
Gold mining		
Insecticides		
Dental amalgam		
Batteries		
Road leveling device in cars		
Mercurochrome		
Electrical tilt switches		
Anti-depressive pills		
Latex paints		
Thermometers		
Children’s maze games		

Unique Properties of Mercury	Implications
♦ Only metal that is liquid at room temperature.	Holds fascination for people of all ages. Special ceremonial uses in several different cultures.
♦ Easily evaporates into the air.	A blob of mercury sitting on the table will eventually disappear. The mercury vapors can be extremely dangerous to breathe.
♦ Very dense, yet fluid.	Just a little bit weighs a lot, yet moves around easily. This is useful in certain medical procedures.
♦ Good conductor of electricity.	Used in electrical tilt switches and other electrical devices.
♦ Expands or contracts uniformly with changes in temperature.	Used in thermometers and thermostats.
♦ Readily combines (amalgamates) with other metals and materials.	Dentists combine it with silver to make amalgam, which is used to fill cavities in teeth.
♦ Kills bacteria and fungi.	Previously used in pesticides, paints and on people to kill germs!



Mercury Right Here and Now

You might have already started by eliminating mercury in your school and home, or maybe you reduced your energy consumption. Now it is time to take even greater action. In order to take community action, you need to know where your community stands. Have the students find out what people know or do not know about mercury by conducting the "Local Survey about Mercury." Once the students have done this, have them report on their findings and the implications of those findings to the full group.

Activity 6 - A Local Survey About Mercury

Objectives:

Students will: 1) design and conduct a survey of their community on the subject of mercury; 2) evaluate the results of the survey and develop an action plan to address the survey findings.

Materials:

Sample Survey

Background:

Are residents in your community concerned about mercury? Do any businesses use mercury in their operations? Does your community have the cleanup equipment to handle a mercury spill? Do residents in your community know about the health threats of mercury? Are any lakes in your region listed in the state fish advisory? Do anglers care?

One method of finding answers to these questions and others is to design a survey and conduct it in your community. It is an interactive process that requires preparation, involvement and interpretation. The results can lead students to take an active role in tackling an environmental problem in their community.

Several different methods can be used to study information and opinions about environmental issues. Here are two different methods.

Surveys can be used to collect information about environmental conditions in your school and community. They focus on information about a specific problem in a certain area. Example: How many mercury thermometers do you have in your home?

Opinionnaires measure the beliefs or opinions of people at a specific time. They are each person's opinion – which might or might not be accurate or correct.

For example:

I believe mercury is dangerous to human health.

Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree

Before a method is selected, it is important that students carefully decide the exact information that needs to be collected, the geographic area they want to cover, and the target population that will be surveyed. A combination of methods can also be used. Accurate collection of the information is next. The students should prepare a data summary sheet to record their information.

Once the data has been collected, students will be challenged to interpret the information and suggest ways to share their results and actions that need to be taken.

A valuable book to assist you in developing and utilizing surveys is, “Investigating and Evaluating Environmental Issues and Actions: Skill Development Modules,” by Harold Hungerford and others. Stipes Publishing Company, 10-12 Chester Street, Champaign, IL 61820

Procedure:

1. Have the students use the sample survey or design a new one to conduct a community survey on the topic of mercury. Students are encouraged to add new questions specially targeted at their community.
2. Students will identify a target audience and conduct the survey. Target audiences could include homeowners, students, or teachers.
3. Tabulate and analyze the results of the survey and prepare a report. Students should then identify various action steps they could take to increase the knowledge of the target audience on the subject of mercury.

Sample Mercury Survey

Hello, my name is _____. I am a student at _____School. I am doing research on mercury in our community. I would like to ask you several questions about this topic. The survey will take about 10 minutes.

Person Responding: Male ____ Female ____
Age: <20 ____ 20-40 ____ 40-60 ____ 60+ ____

1. Do you consider mercury dangerous to human health? Yes ____ No ____

2. In the last year, have you heard or read of any local or national news story that describes an incident involving mercury? Yes ____ No ____

3. Do you fish? Yes ____ No ____
If yes, have you consulted the state fish advisory that describes the warnings for eating fish from certain bodies of water? Yes ____ No ____

For each of the following statements, tell me whether you strongly agree, agree, neutral, disagree, or strongly disagree.

4. All thermometers contain mercury.
Strongly Agree *Agree* *Neutral* *Disagree* *Strongly Disagree*

5. Mercury should be stored in locked cabinets if it is used at school.
Strongly Agree *Agree* *Neutral* *Disagree* *Strongly Disagree*

6. Switches and thermostats that contain mercury should be clearly labeled.
Strongly Agree *Agree* *Neutral* *Disagree* *Strongly Disagree*

Please rate on a scale of 1 (not important) to 5 (very important) the following statements:

7. Mercury should be banned from use in children's toys.
1 2 3 4 5

8. Non-essential uses of mercury should be phased out in our community.
1 2 3 4 5

9. Firefighters and emergency personnel should be trained to handle a mercury spill.
1 2 3 4 5

Please answer True or False to the following:

T ____ F ____ 10. Mercury spills in schools have resulted in evacuations and expensive cleanups.

T ____ F ____ 11. Several different cultures use mercury for ceremonial or religious purposes.

T ____ F ____ 12. Once mercury gets into your body, it might stay there for several weeks.

T ____ F ____ 13. The burning of fossil fuels such as coal releases mercury into the air.

Please answer the following questions:

14. What would you do if you found a jar of mercury in your basement?

15. Do you read and follow the advice given in our state's Fish Consumption Advisory? Why or Why not?

16. What are the symptoms of mercury poisoning?

17. Circle the household items that might contain mercury.

thermometers	kid's maze games
mercurochrome	hair shampoo
switches in old washing machines and freezers	sphygmomanometers
most plastics	some nasal sprays

Thank you.

Now might be the time to take community action. Your class or a group of students might wish to develop a community action plan. This activity can be done at the beginning of the project; then you will need to revise the plan based on what the students learned from the previous activities. Or you might wish to do the plan at the end of your class mercury activities.

Activity 7- Mercury Community Action Projects

Objective:

Students will develop and implement an action plan to reduce the concerns and effects of mercury in their community.

Materials:

Background materials in this set of activities.

Background:

Your students will be participating in the "real world"! Completing a "Community Action Project" is based on the following assumptions:

- Society must solve community environmental issues with participation from its young members.
- Students need to know they can be forces for constructive change.
- Students need the opportunity to investigate and act upon a problem of their choice to increase their motivation to learn.
- The school and its community need to be connected to show relevance to the real world. The classroom is part of the community and the community is part of the classroom.

The Community Action Project will provide the students an opportunity to apply the knowledge they have acquired about mercury to improve how mercury is handled in the community. The students will use skills in research, investigation, problem-solving and working in groups.

Procedure

Students can undertake this activity as a class or in groups. They will brainstorm a list of recommendations for their community on mercury reduction. Based on this list, they will choose one activity and develop an action plan that will include the following:

- Identify the problem to be addressed;
- List methods to address the problem;
- Select the best action
- Determine the resources needed to complete the plan;
- Identify possible partners for the program;
- Develop a time line;
- Implement the project; and
- Evaluate the project and suggest changes for future efforts.

The class or groups will then implement their action plan.

The following are some possible activities that the students can develop for action plans:

- Organize a community outreach program about mercury; for example, create a display and handout(s) about mercury and take them to various public venues.

- Discuss mercury spill prevention and cleanup with school janitorial staff, local fire department and/or Hazmat (hazardous materials) Team.

- Promote a mercury or household hazardous waste collection program in your community.

- Design and print labels for equipment that contains mercury and work with school janitorial staff, nursing homes and/or others to place these on mercury thermostats and other equipment;

- Check store inventories and work with store owners to ensure that no mercury-containing games (e.g. maze games or toys) are being sold to small children.

- “Adopt” a hospital or nursing home and work with them to minimize their use of mercury and safely recycle their existing mercury.

- Work with your electric utility to promote a mercury thermostat recycling program.

- Perform mercury school audits for grade schools and middle schools in your school district.

- Determine if there are any rules pertaining to mercury in your community or state, and, if not, start a campaign to establish rules.

- Investigate what popular stores in your community or state are doing about the sale of items containing mercury.

- Other ideas from the students