MARINE CONSERVATION SCIENCE AND POLICY SERVICE LEARNING PROGRAM

Bioaccumulation is the gradual build up over time of a chemical in a living organism. This occurs either because the chemical is taken up faster than it can be used, or because the chemical cannot be broken down for use by the organism (that is, the chemical cannot be metabolized). Bioaccumulation need not be a concern if the accumulated compound is not harmful. Compounds that are harmful to health, such as mercury, however, can accumulate in living tissues. **Mercury contamination** is a good example of the bioaccumulation process. Typically, mercury (or a chemical version called methylmercury) is taken up by bacteria and phytoplankton. Small fish eat the bacteria and phytoplankton and accumulate the mercury. The small fish are in turn eaten by larger fish, which can become food for humans and animals. The result can be the build up (biomagnification) of large concentrations of mercury in human and animal tissue.

MODULE 5: MANAGEMENT, CONSERVATION, RESEARCH AND ACTIONS

SECTION 3: MERCURY TOXICITY DATA

SUNSHINE STATE STANDARDS

SC.912.L.17.16, SC.912.E.6.6, SC.912.L.16.10, SC.912.L.17.17, SC.912.L.17.9

OBJECTIVES

- Understand the concepts of bioaccumulation and biomagnification
- Learn about how mercury is stored in different trophic levels.
- Create awareness about mercury toxicity in the environment and its consequences.

VOCABULARY

Bioaccumulation- refers to the accumulation of substances, such as pesticides, or other organic chemicals in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is lost.

Biomagnification- also known as bioamplification or biological magnification, is the increase in concentration of a substance, such as the pesticide DDT, that occurs in a food chain as a consequence of: Persistence (can't be broken down by environmental processes); Food chain energetics; Low (or nonexistent) rate of internal degradation/excretion of the substance (often due to water-insolubility).

Food chains- and food webs are representations of the predator-prey relationships between species within an ecosystem or habitat.

Mercury- is a chemical element with the symbol Hg and atomic number 80. Mercury is the only metal that is liquid at standard conditions for temperature and pressure.

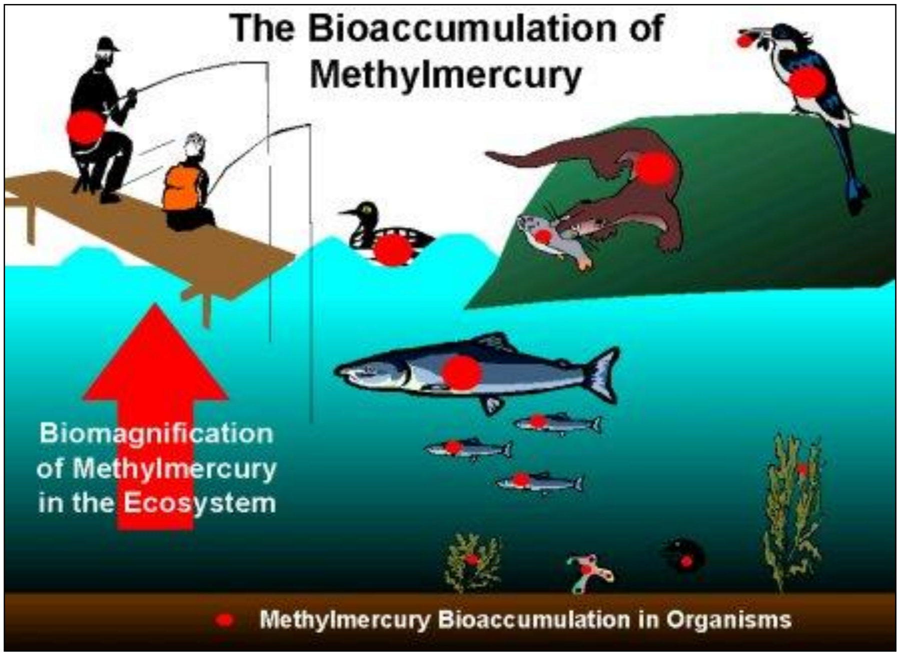
Mercury poisoning- is a disease caused by exposure to mercury or its compounds.

The trophic level of an organism is the position it occupies on the food web.

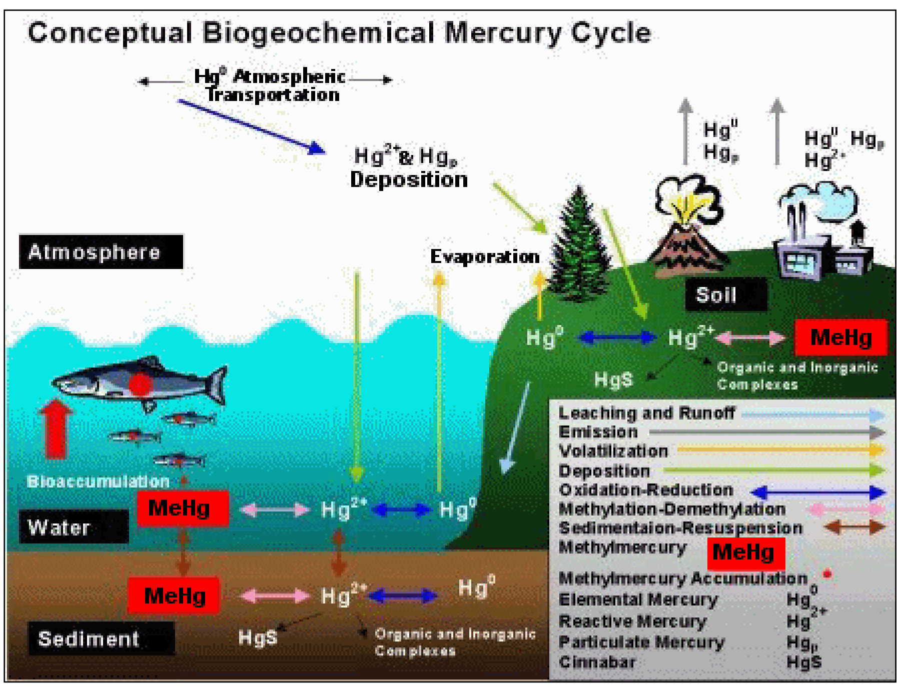
BACKGROUND

Mercury is a highly toxic element that is found both naturally and as an introduced contaminant in the environment. Although its potential for toxicity in highly contaminated areas such as Minamata Bay, Japan, in the 1950's and 1960's, is well documented, research has shown that mercury can be a threat to the health of people and wildlife in many environments that are not obviously polluted. The risk is determined by the likelihood of exposure, the form of mercury present (some forms are more toxic than others), and the geochemical and ecological factors that influence how mercury moves and changes form in the environment.

Toxic Effects



The toxic effects of mercury depend on its chemical form and the route of exposure. Methylmercury [CH3Hg] is the most toxic form. It affects the immune system, alters genetic and enzyme systems, and damages the nervous system, including coordination and the senses of touch, taste, and sight. Methylmercury is particularly damaging to developing embryos, which are five to ten times more sensitive than adults. Exposure to methylmercury is usually by ingestion, and it is absorbed more readily and excreted more slowly than other forms of mercury. Elemental mercury, Hg(0), the form released from broken thermometers, causes tremors, gingivitis, and excitability when vapors are inhaled over a long period of time. Although it is less toxic than methylmercury, elemental mercury may be found in higher concentrations in environments such as gold mine sites, where it has been used to extract gold. If elemental mercury is ingested, it is absorbed relatively slowly and may pass through the digestive system without causing damage. Ingestion of other common forms of mercury, such as the salt HgCl2, which damages the gastrointestinal tract and causes kidney failure, is unlikely from environmental sources.

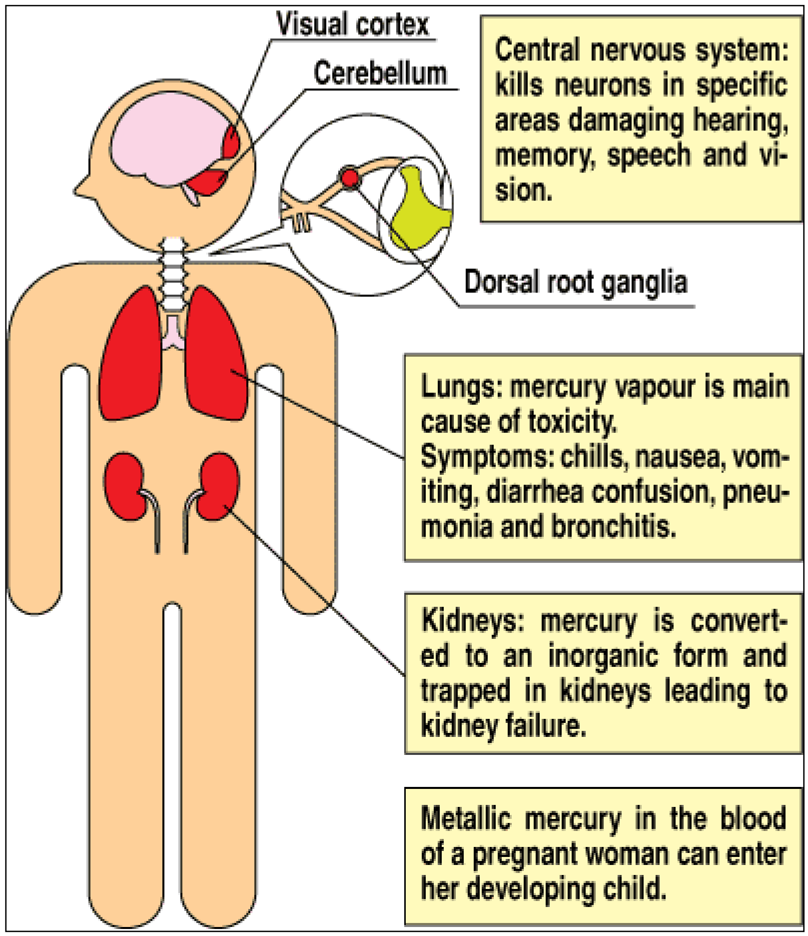


Risk to People

People are exposed to

methylmercury almost entirely by eating contaminated fish and wildlife that are at the top of aquatic foodchains. The National Research Council, in its 2000 report on the toxicological effects of methylmercury, pointed out that the population at highest risk is the offspring of women who consume large amounts of fish and seafood. The report went on to estimate that more than 60,000 children are born each year at risk for adverse neurodevelopmental effects due to in utero exposure to methylmercury. In its 1997 Mercury Study Report to Congress, the U.S. Environmental Protection Agency concluded that mercury also may pose a risk to some adults and wildlife populations that consume large amounts of fish that is contaminated by mercury.

Bioaccumulation, Bioconcentration and Biomagnification

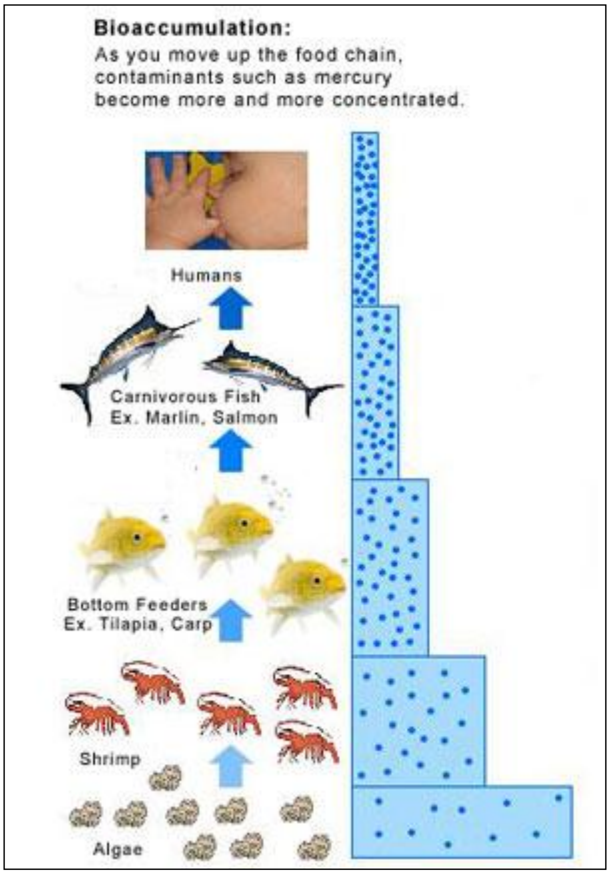


Bioaccumulation refers to the accumulation of substances, such as pesticides, or other organic chemicals in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is lost. Thus, the longer the biological half-life of the substance the greater the risk of chronic poisoning, even if environmental levels of the toxin are not very high.

Bioconcentration is a related but more specific term, referring to uptake and accumulation of a substance from water alone. By contrast, bioaccumulation refers to uptake from all sources combined (e.g. water, food, air, etc.)

An example of poisoning in the workplace can be seen from the phrase "as mad as a hatter". The process for stiffening the felt used in making hats involved mercury, which forms organic species such as methylmercury, which is lipid soluble, and tends to accumulate in the brain resulting in mercury poisoning.

Other lipid (fat) soluble poisons include tetra-ethyl lead compounds (the lead in leaded petrol), and DDT. These compounds are stored in the body's fat, and when the fatty tissues are used for energy, the compounds are released and cause acute poisoning.



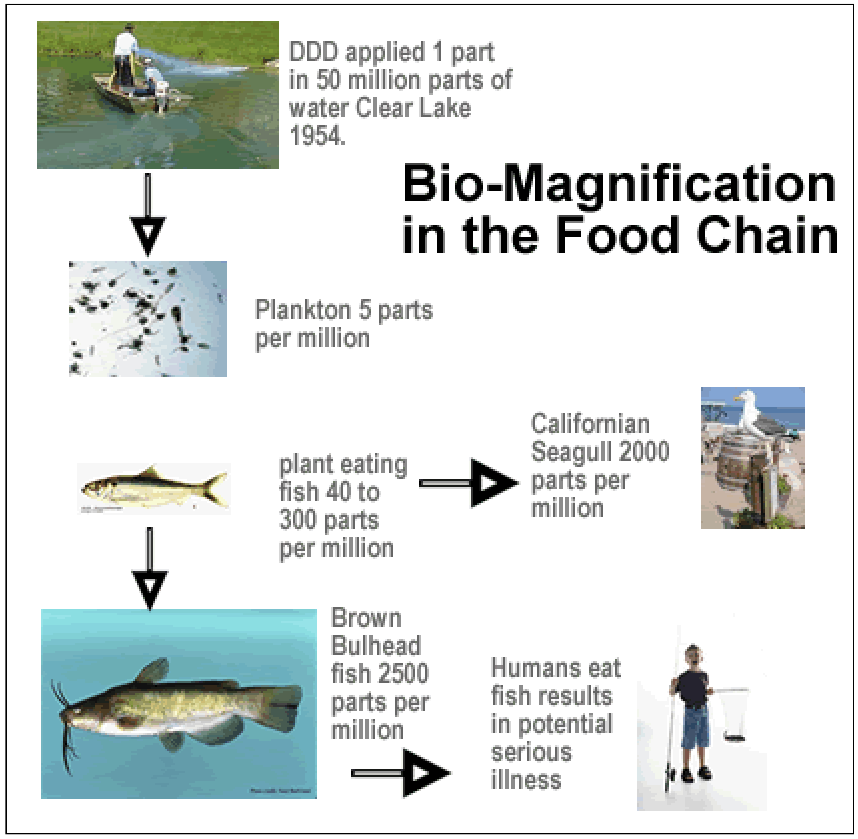
Strontium-90, part of the fallout from atomic bombs, is chemically similar enough to calcium that it is utilized in osteogenesis, where its radiation can cause damage for a long time.

Naturally produced toxins can also bioaccumulate. The marine algal blooms known as "red tides" can result in local filter feeding organisms such as mussels and oysters becoming toxic; coral fish can be responsible for the poisoning known as ciguatera when they accumulate a toxin called ciguatoxin from reef algae.

Some animal species exhibit bioaccumulation as a mode of defense; by consuming toxic plants or animal prey, a species may accumulate the toxin which then presents a deterrent to a potential predator. One example is the tobacco hornworm, which concentrates nicotine to a toxic level in its body as it consumes tobacco plants. Poisoning of small consumers can be passed along the food chain to affect the consumers later on. Other compounds that are not normally considered toxic can be accumulated to toxic levels in organisms. The classic example is of Vitamin A, which becomes concentrated in carnivore livers of e.g. polar bears: as a pure carnivore that feeds on other carnivores (seals), they accumulate extremely large amounts of Vitamin A in their livers. It was known by the native peoples of the Arctic that the livers should not be eaten, but Arctic explorers have suffered Hypervitaminosis A from eating the bear livers (and there has been at least one example of similar poisoning of Antarctic explorers eating husky dog livers). One notable example of this is the expedition of Sir Douglas Mawson, where his exploration companion died from eating the liver of one of their dogs.

Coastal fish (such as the smooth toadfish) and seabirds (such as the Atlantic Puffin) are often monitored for heavy metal bioaccumulation .

In some eutrophic aquatic systems, biodilution can occur. This trend is a decrease in a comtaminant with in increase in trophic level and is due to higher concentrations of algae and bacteria to "dilute" the concentration of the pollutant.



Biomagnification, also known as bioamplification or biological magnification, is the increase in concentration of a substance, such as the pesticide DDT, that occurs in a food chain as a consequence of:

- Persistence (can't be broken down by environmental processes)
- Food chain energetics
- Low (or nonexistent) rate of internal degradation/excretion of the substance (often due to water-insolubility)

Biological magnification often refers to the process whereby certain substances such as pesticides or heavy metals move up the food chain, work their way into rivers or lakes, and are eaten by aquatic organisms such as fish, which in turn are eaten by large birds, animals or humans. The substances become concentrated in tissues or internal organs as they move up the chain. Bioaccumulants are substances that increase in concentration in living organisms as they take in contaminated air, water, or food because the substances are very slowly metabolized or excreted.

Although sometimes used interchangeably with 'bioaccumulation,' an important distinction is drawn between the two, and with bioconcentration, it is also important to distinct between sustainable development and overexploitation in biomagnification.

Bioaccumulation occurs within a trophic level, and is the increase in concentration of a substance in certain tissues of organisms' bodies due to absorption from food and the environment.

Bioconcentration is defined as occurring when uptake from the water is greater than excretion (Landrum and Fisher, 1999).

Thus bioconcentration and bioaccumulation occur within an organism, and biomagnification occurs across trophic (food chain) levels.

Biodilution is also a process that occurs to all trophic levels in an aquatic environment; it is the opposite of biomagnification, thus a pollutant gets smaller in concentration as it progresses up a food web.

Lipid, (lipophilic) or fat soluble substances cannot be diluted, broken down, or excreted in urine, a water-based medium, and so accumulate in fatty tissues of an organism if the organism lacks enzymes to degrade them. When eaten by another organism, fats are absorbed in the gut, carrying the substance, which then accumulates in the fats of the predator. Since at each level of the food chain there is a lot of energy loss, a predator must consume many prey, including all of their lipophilic substances.

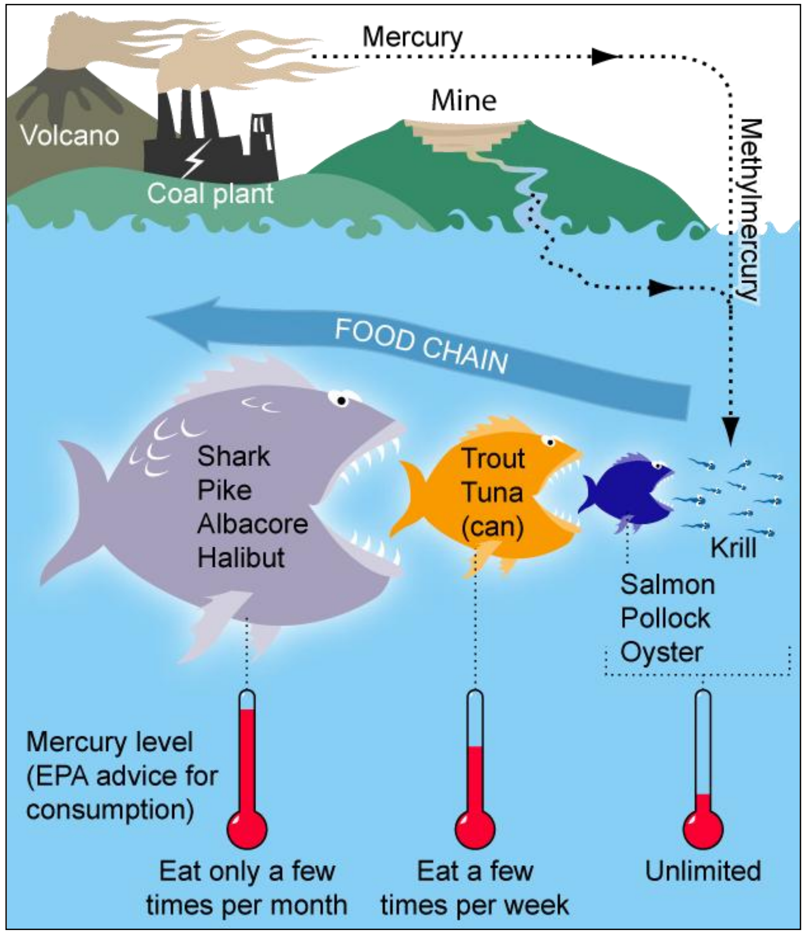
For example, though mercury is only present in small amounts in seawater, it is absorbed by algae (generally as methylmercury). It is efficiently absorbed, but only very slowly excreted by organisms (Croteau et al., 2005). Bioaccumulation and bioconcentration result in buildup in the adipose tissue of successive trophic levels: zooplankton, small nekton, larger fish etc. Anything which eats these fish also consumes the higher level of mercury the fish have accumulated. This process explains why predatory fish such as swordfish and sharks or birds like osprey and eagles have higher concentrations of mercury in their tissue than could be accounted for by direct exposure alone. For example, herring contains mercury at approximately 0.01 ppm and shark contains mercury at greater than 1 ppm (EPA 1997).

Mercury in fish

Fish and shellfish concentrate mercury in their bodies, often in the form of methylmercury, a highly toxic organic compound of mercury. Fish products have been shown to contain varying amounts of heavy metals, particularly mercury and fat-soluble pollutants from water pollution. Species of fish that are long-lived and high on the food chain, such as marlin, tuna, shark, swordfish, king mackerel, tilefish, northern pike, and lake trout contain higher concentrations of mercury than others.

The presence of mercury in fish can be a health issue, particularly for women who are or may become pregnant, nursing mothers, and young children.

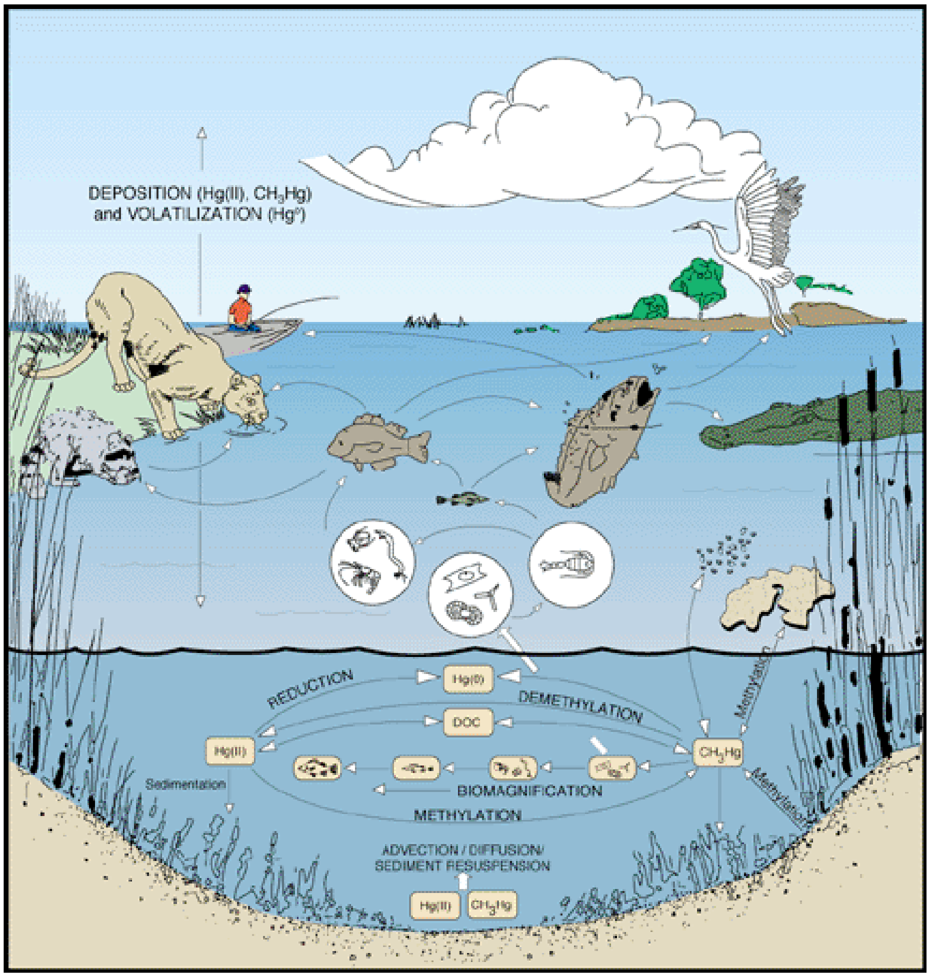
Biomagnification of Mercury



Mercury and methylmercury is present in only small concentrations in seawater. However, it is absorbed, usually as methylmercury, by algae at the start of the food chain. This algae is then eaten by fish and other organisms higher in the food chain. Fish efficiently absorb methylmercury, but only very slowly excrete it. Methylmercury is not soluble and therefore is not apt to be excreted. Instead, it accumulates, primarily in the viscera although also in the muscle tissue. This results in the bioaccumulation of mercury, in a buildup in the adipose tissue of successive trophic levels: zooplankton, small nekton, larger fish etc. Anything which eats these fish within the food chain also consumes the higher level of mercury the fish have accumulated. This process explains why predatory fish such as swordfish and sharks or birds like osprey and eagles have higher concentrations of mercury in their tissue than could be accounted for by direct exposure alone. Species on the food chain can amass body concentrations of mercury up to ten times higher than the species they consume. This process is called biomagnification. For example, herring contains mercury levels at about 0.01 ppm while shark contains mercury levels greater than 1 ppm.

Sources of Mercury in the environment

Much of the mercury that eventually finds its way into fish originates with coal-burning power plants and chlorine production plants. The largest source of mercury contamination in the United States is coal-fueled power plant emissions.[3] Chlorine chemical plants use mercury to extract chlorine from salt, which in many parts of the world is discharged as mercury compounds in waste water though this process has been replaced for the most part by the more economically viable membrane cell process, which does not use mercury. Coal contains mercury as a natural contaminant. When it is fired for electricity generation, the mercury is released as smoke into the atmosphere. Most of this mercury pollution can be eliminated if pollution-control devices are installed



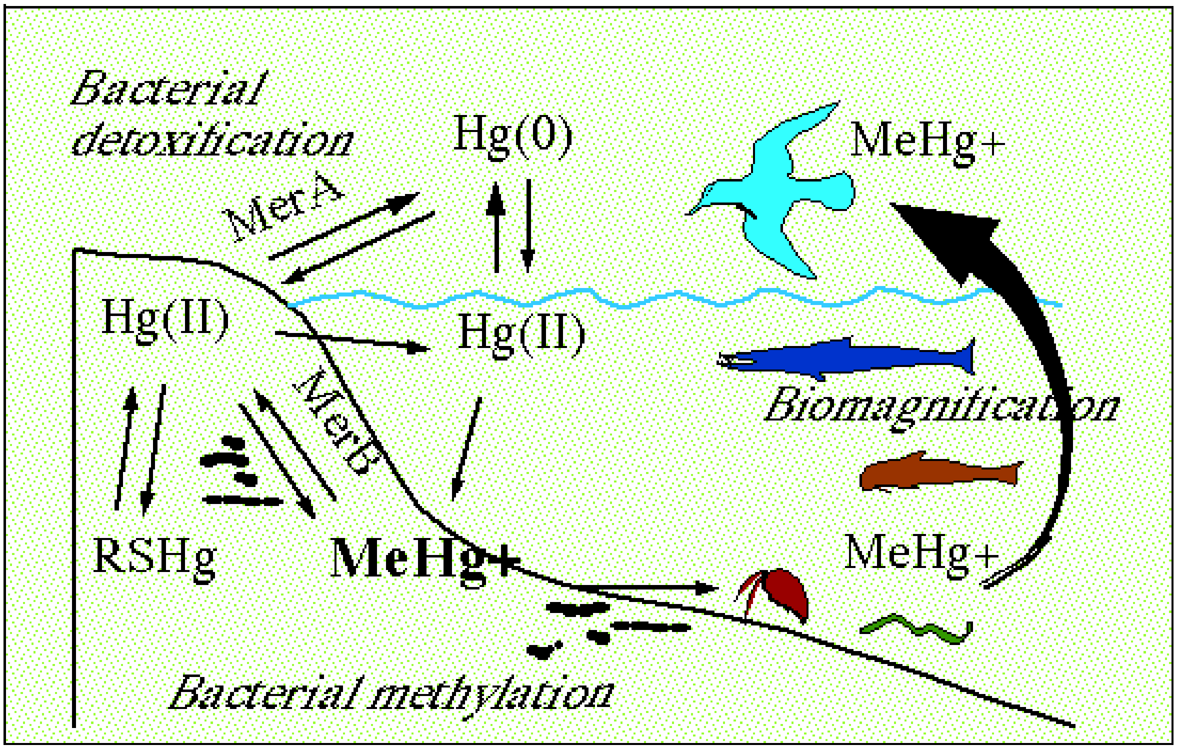
Alkali and metal processing, incineration of coal, and medical and other waste, and mining of gold and mercury contribute greatly to mercury concentrations in some areas, but atmospheric deposition is the dominant source of mercury over most of the landscape. Once in the atmosphere, mercury is widely disseminated and can circulate for years, accounting for its wide-spread distribution. Natural sources of atmospheric mercury include volcanoes, geologic deposits of mercury, and volatilization from the ocean. Although all rocks, sediments, water, and soils naturally contain small but varying amounts of mercury, scientists have found some local mineral occurrences and thermal springs that are naturally high in mercury.

What factors affect the methylation?

Methylation is a product of complex processes that move and transform mercury. Atmospheric deposition contains the three principal forms of mercury, although inorganic divalent mercury (HgII) is the dominant form. Once in surface water, mercury enters a complex cycle in which one form can be converted to another. Mercury attached to particles can settle onto the sediments where it can diffuse into the water column, be resuspended, be buried by other sediments, or be methylated. Methylmercury can enter the food chain, or it can be released back to the atmosphere by volatilization.

The concentration of dissolved organic carbon (DOC) and pH have a strong effect on the ultimate fate of mercury in an ecosystem. Studies have shown that for the same species of fish taken from the same region, increasing the acidity of the water (decreasing pH) and/or the DOC content generally results in higher mercury levels in fish, an indicator of greater net methylation. Higher acidity and DOC levels enhance the mobility of mercury in the environment, thus making it more likely to enter the food chain.

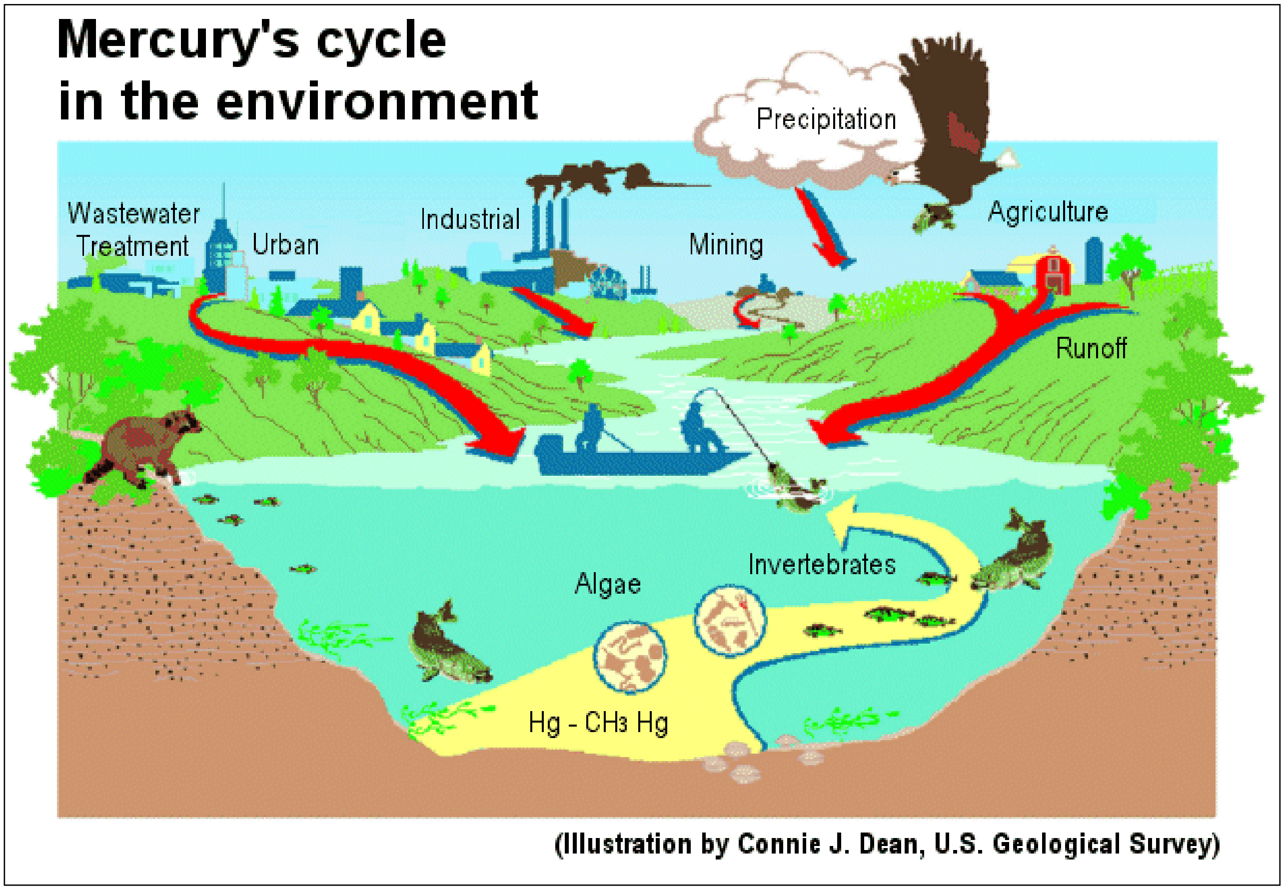
Mercury and methylmercury exposure to sunlight (specifically ultra-violet light) has an overall detoxifying effect. Sunlight can break down methylmercury to Hg(II) or Hg(0), which can leave the aquatic environment and reenter the atmosphere as a gas.



Environments Where Methylmercury is a Problem

Although mercury is a globally dispersed contaminant, it is not a problem everywhere. Aside from grossly polluted environments, mercury is normally a problem only where the rate of natural formation of methylmercury from inorganic mercury is greater than the reverse reaction. Methylmercury is the only form of mercury that accumulates appreciably in fish. Environments that are known to favor the production of methylmercury include certain types of wetlands, dilute low-pH lakes in Northeast and Northcentral United States, parts of the Florida Everglades, newly flooded reservoirs, and coastal wetlands, particularly along the Gulf of Mexico, Atlantic Ocean, and San Francisco Bay.

How does mercury enter the food chain?



(Illustration by Connie J. Dean, U.S. Geological Survey)

The exact mechanisms by which mercury enters the food chain remain largely unknown and may vary among ecosystems. Certain bacteria play an important early role. Bacteria that process sulfate (SO4=) in the environment take up mercury in its inorganic form and convert it to methylmercury through metabolic processes. The conversion of inorganic mercury to methylmercury is important because its toxicity is greater and because organisms require considerably longer to eliminate methylmercury. These methylmercury-containing bacteria may be consumed by the next higher level in the food chain, or the bacteria may excrete the methylmercury to the water where it can quickly adsorb to plankton, which are also consumed by the next level in the food chain. Because animals accumulate methylmercury faster than they eliminate it, animals consume higher concentrations of mercury at each successive level of the food chain. Small environmental concentrations of methy-lmercury can thus readily accumulate to potentially harmful concentrations in fish, fish-eating wildlife and people. Even at very low atmospheric deposition rates in locations remote from point sources, mercury biomagnification can result in toxic effects in consumers at the top of these aquatic food chains.

Mercury Contamination - Past, Present, and Future

In highly polluted areas where mercury has accumulated through industrial or mining activities, natural processes may bury, dilute, or erode the mercury deposits, resulting in declines in concentration. In many relatively pristine areas, however, mercury concentrations have actually increased because atmospheric deposition has increased. For instance, concentrations of mercury in feathers of fish-eating seabirds from the northeastern Atlantic Ocean have steadily increased for more than a century. In North American sediment cores, sediments deposited since industrialization have mercury concentrations about 3-5 times those found in older sediments. Some sites may have become methylmercury hot spots inadvertently through human activities. Lake acidification, addition of substances like sulfur that stimulate methylation, and mobilization of mercury in soils in newly flooded reservoirs or constructed wetlands have been shown to increase the likelihood that mercury will become a problem in fish. Although scientists from USGS and elsewhere are beginning to unravel the complex interactions between mercury and the environment, a lack of information on the sources, behavior, and effects of mercury in the environment has impeded identification of effective management responses to the Nation's growing mercury problem.

How can I avoid consuming mercury in fish?

Options for avoiding the mercury in mercury-contaminated fish are more limited than for fish contaminated with PCBs, dioxins and other organic contaminants. Younger fish tend to have lower concentrations of mercury than older, larger fish within the same waterbody. Mercury concentrates in the muscle tissue of fish. So, unlike PCBs, dioxins and other organic contaminants that concentrate in the skin and fat, mercury cannot be filleted or cooked out of consumable game fish.

Risk to Wildlife

In several areas of the United States, concentrations of mercury in fish and wildlife are high enough to be a risk to wildlife. It is difficult to prove cause and effect in field studies, however, because other factors that may contribute to the biological effect under study (for example, reproductive success) are often impossible to control. Scientists have discovered toxic effects in the field at concentrations of mercury that are toxic in the lab, and controlled lab studies have found toxic effects at concentrations that are common in certain environments. In studies in Wisconsin, reductions in loon chick production has been found in lakes where mercury concentrations in eggs exceed concentrations that are toxic in laboratory studies. At dietary mercury concentrations that are typical of parts of the Everglades, the behavior of juvenile great egrets can be affected. Studies with mallards, great egrets, and other aquatic birds have shown that protective enzymes are less effective following exposure to mercury. Analyses of such biochemical indicators indicate that mercury is adversely affecting diving ducks from the San Francisco Bay, herons and egrets from the Carson River, Nevada, and heron embryos from colonies along the Mississippi River. Finally, other contaminants also affect the toxicity of mercury. Methylmercury can be more harmful to bird embryos when selenium, another potentially toxic element, is present in the diet.

Fish Advisories

The steadily increasing number and geographic extent of State advisories against the consumption of fish because of mercury contamination has raised the awareness of the widespread nature of the mercury hazard. Fish consumption advisories for methylmercury now account for more than three-quarters of all fish consumption advisories in the United States. Forty States have issued advisories for methylmercury on selected water-bodies and 13 states have statewide advisories for some or all sportfish from rivers or lakes. Coastal areas along the Gulf of Mexico, Maine, and the Atlantic Ocean from Florida through North Carolina are under advisories for methylmercury for certain fish.

Current advice

The complexities associated with mercury transport and environmental fate are described by USEPA in their 1997 Mercury Study Report to Congress. Because methylmercury and high levels of elemental mercury can be particularly toxic to a fetus or young children, organizations such as the U.S. EPA and FDA recommend that women who are pregnant or plan to become pregnant within the next one or two years, as well as young children avoid eating more than 6 ounces (one average meal) of fish per week.

In the United States, the FDA has an action level for methylmercury in commercial marine and freshwater fish that is 1.0 parts per million (ppm). In Canada, the limit for the total of mercury content is 0.5 ppm. The Got Mercury? website includes a calculator for determining mercury levels in fish.

Species with characteristically low levels of mercury include shrimp, tilapia, salmon, pollock, and catfish (FDA March 2004). The FDA characterizes shrimp, catfish, pollock, salmon, sardines, and canned light tuna as low-mercury seafood, although recent tests have indicated that up to 6 percent of canned light tuna may contain high levels. A study published in 2008 found that mercury distribution in tuna meat is inversely related to the lipid content, suggesting that the lipid concentration within edible tuna tissues has a diluting effect on mercury content. These findings suggest that choosing to consume a type of tuna that has a higher natural fat content may help reduce the amount of mercury intake, compared to consuming tuna with a low fat content. Also, many of the fish chosen for sushi contain high levels of mercury.

According to the US Food and Drug Administration (FDA), the risk from mercury by eating fish and shellfish shall not be a health concern for most people. However, certain seafood might contain levels of mercury to harm an unborn baby (and especially its brain development and nervous system) or in cases of young child's interfere with the development of the nervous system. The FDA provides three recommendations for young children, pregnant women, and women of child-bearing age:

1. Do not eat shark, swordfish, king mackerel, or tilefish because they might contain high levels of mercury.
2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury. Five of the most commonly eaten fish and shellfish that are low in mercury are: shrimp, canned light tuna, salmon, pollock, and catfish. Another commonly eaten fish, albacore or big eye ("white") tuna depending on its origin might have more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, it is recommended that you should not eat more than up to 6 ounces (one average meal) of albacore tuna per week.
3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but consume no other fish during that week.

These recommendations should be considered when feeding fish and shellfish to young children, but in proportionally smaller and controlled quantities.

Activity: Biological Magnification (Bioaccumulation)

The activity is found on the idea of biological magnification: the increased concentration of nonbiodegradable chemicals in the higher levels of the food chain. Since the chemicals are not biodegradable, animals absorbed them and store them in fat. Once a fish eats another fish, for example, the waste is passed on and thus becomes more concentrated.

Summary of Activity

Five different size beakers with about 50 mL of water are laid on the table, representing 5 different levels of the food chain. Add one drop of food coloring to each beaker, representing the bio-waste material that all marine animals are exposed to through absorption from the water. Then as we move up the sizes of the beakers, add one more drop of food coloring, showing the effect of concentrated and nonbiodegradable waste as we move up the food chain. The color of the water in the last beaker should be very dark. Then, soak a piece of bread in the last beaker, showing the students the possibility of humans eating a big fish, containing the most concentrated toxin. Ask the students if anyone would want to eat the piece of bread with the toxin in it. Lastly, give the students some information on marine mammal young that are affected by the biological magnification or bioaccumulation, i.e., whales rely on blubber and mom's milk when they are young and vulnerable, etc.

Duration: 1 hour

Objectives

- Understand biological magnification
- Understand the food chain
- Create discussion on how it can be prevented

Materials

For each group of 4 students:

- 5 different size beakers,
- water (about 250 mL),
- food coloring,
- a piece of bread,
- construction paper and crayons/colored pencils,
- tape/paste.

For discussion:

- A diagram of the food chain

BACKGROUND INFORMATION

Pollutants in the sea sometimes originated from land; they are toxic chemicals that are synthetic, that is, manufactured by humans. Although they are organic, being artificial, they are foreign to many forms of life. One major group of synthetic chemical pollutants are the chlorinated hydrocarbons, used in pesticides to kill insects and to control weeds. Many of these pesticides saved people from diseases and starvation, but they also are harmful tom any other organisms if used unchecked.

Pesticides have not been used directly in the ocean; however, they are very mobile. They are carried by wind, especially when crops are sprayed from planes. They are brought into the ocean from rivers, runoff from land, and domestic sewage. Pesticides are then absorbed by plankton and move up the levels of the food chain. Since chlorinated hydrocarbons are synthetic, organisms have not learned a way to break them down; thus, they are nonbiodegradable. Chlorinated carbons are not very soluble in water, persist through many years in the environment and accumulate in fats. Because the pesticides are persistent, the higher an organism is on the food chain, the higher concentration of toxic pesticides are in it. The pesticides are passed from one organism to the next, getting more and more harmful because it cannot be broken down through digestion or by the liver of the animals that eat them. Whales are one of the top carnivores in the ocean; thus, they are very susceptible to biological magnification. Furthermore, chlorinated carbons accumulate in fast, and pups rely on their blubber and their mom's milk (which is made directly from fat) for food. Toxin is passed onto the pups with a weak immunity system in this way. Therefore, many pups die before the age of one.

PROCEDURE

1. Have the materials ready for the students and the food chain diagram for the discussion.

2. Creating the animals: This is done by the students in groups of 4.
    - Draw the animals on construction papers: algae/plankton, small fish, salmon (medium size fish), herring, whale/shark.
    - Color the animals with colored pencils and crayons
    - Paste/tape the paper animal on the outside of the beakers. (One animal per beaker).
    - Fill the beakers with approximately 50 mL of water. Discussion: This is done with the class as a whole.
    - Ask for the definition of a food chain.
    - Explain the concepts of a food chain as needed.
    - Explain that the beakers represent different organisms in the ocean.
    - Ask students to point out members that are the top/bottom of the food chain among the beakers.
    - Ask for a definition of toxic chemicals.

- Explain biodegradable vs. nonbiodegradable Main activity:
- Have the students go back into their original groups of 4 and give them food coloring and their set of decorated beakers filled with 50 mL of water.
- Give out instructions as follow:

- Add one drop of food coloring to all beakers, exposing all animals to the pesticides.
- Starting with the plankton: what eats the plankton?
- Small fish eats the plankton, thus concentrating more toxin in itself, demonstrate this by adding one more drop of food coloring ot the small fish beaker.
- What eats the small fishes?--salmon. Add 2 drops of food coloring to the salmon beaker. (One drop comes from the plankton, the other from the small fish).
- Continue with the herring. Add 3 drops.
- With the shark/whale, add 4 drops.
- Can human eat the top predators of the ocean?
- Soak the piece of bread into the shark/whale beaker, adding 5 drops of food coloring to the bread, thus concentrate it further.
- Calculate the amount of toxin humans get if we eat a fish that is at the top of the food chain (how many drops?)
- Any volunteers to eat the piece of bread?

Questions

Since we do not want to eat the piece of bread with a lot of toxin in it, do you think the big fishes in the ocean want to? Why or why not?

____
____

How can we stop or prevent biological magnification?

____
____
____

How can we stop it from continuing to harm marine animals and humans who eat them?

____
____
____

Conclusion

Synthetic (man-made) materials such as pesticides can be extremely harmful to marine animals. To prevent hurting the marine organisms and others who eat them, including humans, we must control our use of synthetic materials. Recycling and simple tasks such as picking up your trash when you're at the beach can help the lives of these animals.

Activity: Environmental Toxics: Alternatives

Duration: 1 hour

Objectives

Students will…

- Formulate non-toxic cleaning products.
- Differentiate observation from inference (interpretation).
- Act like scientists, deriving explanations from observations and inferences.
- Formulate and justify predictions based on cause-and-effect relationships.
- Conduct multiple trials to test a prediction and draw conclusions about the relationship between predictions and results.
- Follow a set of written instructions for a scientific investigation.
- Measure and estimate the volume of ingredients.

Overview

Students analyze the warning labels on toxic cleaning products and discuss health consequences. They use their observations and inferences to design and test formulas for non-toxic cleaners using safe, household ingredients. The students ask their own questions and practice following written instructions with careful measurements. Groups work together to compare results from multiple trials.

Key Terms

- Observation- Something seen, or a statement made by looking at something.
- Inference- A statement or conclusion based assumed facts.
- Alternative- A different choice from the usual or conventional one.
- Safe: Harmless.
- Hazardous- Involving or exposing one to danger, harm, or risk.
- Ingredient- Something that is a part of any combination or mixture.
- Substitute- A person or thing that takes the place or function of another.

Occupation of the Day

Chemist: A scientist who works with chemicals. Chemists can work for universities, research institutions, government agencies, or companies. Some chemists formulate and test chemical products such as shampoo, paint, glue, and cleaning products.

Materials

Per student:

- 1 worksheet

Per Group of 4

- 2 warning labels or empty containers from toxic cleaning products. It helps to enlarge labels on a photocopier. Each group can have the same labels.
- 1 measuring cup. Either _ cup or _ cup will do.
- 1 teaspoon
- 1 tablespoon
- 4 mixing bowls (1 for each trial). Almost any plastic container or large plastic cup will work. It should hold at least 2 cups.
- 4 stirring sticks. Coffee stirrers work well.
- cup vinegar in a small container (buy one 12-oz. container for the class)
- cup salt in a small container
- cup of flour in a small container
- 1/8 cup lemon juice in a small container
- cup baking soda in a small container
- cup vegetable oil
- 5 paper towels
- liter water

Procedure

Questions:
How do household cleaning products harm human health and the environment?

How would you invent a non-toxic cleaning product?

Activity

1. Pass out labels or product containers to each group. Discuss the health risks and environmental damage associated with the products. Ask if the students use any of the products at home. Discuss possible solutions and alternatives.
2. Hold up common food ingredients including baking soda, lemon juice, vinegar, flour, vegetable oil and salt. What are the ingredients commonly used for? Are they toxic? How would you know? Differentiate between observations and inferences.
3. Explain that scientists working for companies formulate chemical products using careful investigations. Challenge the class to act as chemists inventing a new, nontoxic cleaner that can remove vegetable oil from a desk. Each group of four students must following these guidelines:
    a. Each group will get the same ingredients.
    b. The group members must take turns performing the roles of writer, measurer, tester, and reporter.
    c. The writer must record the exact measurements and step-by-step instructions for creating and using the product before the group touches

the ingredients. The group must use estimation skills to determine the amount of each ingredient, so that they won't run out of ingredients. The group members should make predictions about the effectiveness of their formula.

d. The measurer must follow the instructions exactly.
e. When each group is ready, the presenter will apply one teaspoon of vegetable oil to one of their desks.
f. The tester must use the new cleaner exactly as the recipe specifies.
g. The reporter must carefully observe and record the results.
h. Each group can do up to 4 trials, as long as they have enough ingredients. The group should base each new trial on the observations and inferences made in the previous trial.

4. After all of the groups are finished, ask them to share their results. What did the groups learn? What can they conclude? Did the results of the tests match their predictions? What were the best ingredients? What ingredients should be avoided? Now that they have tested a few formulas, what questions would they like to investigate? What other ingredients or cleaning methods would they use?
5. Allow time for the students to copy their favorite formulas onto their own worksheets, so that they can share the investigation with their families and friends.

Environmental Toxics: Test the Alternatives
Worksheet

Name:____

Date: ____

Warning Label:

1. What are the health precautions?

____

2. How could this product harm someone?

____

3. What could someone do if he/she is poisoned?

____

4. Name at least one ingredient: ______________________________________

Non-Toxic Cleaner:

Circle the best ingredient for a non-toxic cleaner.

Sugar salt lemon juice flour baking soda

Vinegar Pepper Soda Corn starch

Garlic Water Alcohol Corn meal

Peppermint

Trial 1:

Amount	Ingredient

Directions:

Results:

What would you change:

Trial 2:

Amount	Ingredient

Directions:

____
____
____
____
____
____
____
____
____
____
____
____

Results:

____
____
____
____

What would you change:

____
____
____

Trial 3:

Amount	Ingredient

Directions:

Results:

What would you change:

Trial 4:

Amount	Ingredient

Directions:

____
____
____
____
____
____
____
____
____
____
____
____

Results:

____
____
____
____

What would you change:

____
____
____

Activity: Mercury in the Environment: Percent Mercury in Coal

Duration: 1-2 hours

Objective

- Find the amount of contaminants (sulfur, arsenic, and mercury) in a sample of coal.

Background

Coal is a solid hydrocarbon (that is, a hydrogen and carbon compound). It has 12 to 50 carbon atoms per molecule and over twice that number of hydrogen atoms. In addition, there are many impurities that are left over from the original organic material that made the coal. Oxygen, nitrogen (from plants), silicon (from shells), aluminum, iron, calcium (from bones), magnesium, sodium, potassium, and phosphorus are common in coal.

Also present are sulfur, mercury, and arsenic, three dangerous pollutants. These elements were not, of course, a part of the living organisms that made the coal. These elements seeped into the coal beds long after they were laid at a time when ocean water flooded the land. Coal seams that are low in sulfur (termed “sweet” instead of “sour”) had a layer of impermeable rock overlaying the coal bed.

In this activity, we are going to find the percent-by-mass of contaminating elements in coal. Our “coal sample” is going to be a Ziploc bag of different colors of plastic beads. Each color represents an element and each bead is an atom. The most common color will be the one that represents carbon. This is not because carbon is the most abundant. Rather, it is because carbon’s mass is six times that of hydrogen. If each plastic bead has the same mass, then there should be 6 times more carbon beads than hydrogen beads (1/2 the number x 12 times the mass).

Preparations

Use a student worksheet to make a simple color key. Listed below are the numbers of grams of each color you would need to make a 1,000-atom sample of “coal”. Ideally, each bag of beads will be a little different so that different lab groups will have different data. You may choose the colors with whatever you have available, but the arsenic and mercury beads will be easier to spot if they are a bright color.

Element	Grams of Beads
Carbon	650
Hydrogen	150
Oxygen	100
Silicon	20 – 40
Calcium	20 – 40
Nitrogen	20 – 40
Sulfur	5 – 30
Arsenic	3 beads
Mercury	1 bead

Note: the average amount of mercury contamination in coal is 70 ppb or 7×10^{-7} %

PROCEDURE

Assign each lab station a coal sample. Pairing students will make the work go faster and will require fewer coal bags. Have the students fill in the symbols and atomic masses before beginning the experiment. Emphasize that a close eye should be kept on all of the beads. If one bead is lost, the data may not be accurate.

Mercury in the Environment: Percent Mercury in coal
Student Handout: Find the Percent Composition of a Coal Sample

Objective: Find the amount of contaminants (sulfur, arsenic, and mercury) in a sample of coal.

Procedure:

1. Write the symbol and atomic mass of each element listed in the table.
2. Divide the colored beads by color. Place the beads into paper cups. BE CAREFUL NOT TO LOSE ANY BEADS!
3. Find the mass of each color.
4. Divide the mass of the beads of each color by the atomic mass. The answer is the number of moles of that element in the sample.
5. Add all of the moles together and record.
6. Divide each elemental mole by the total moles and then multiply by 100. The answer is the percentage of that element to the whole sample.
7. After the lab, answer the concluding questions below.

Color	Symbol	Element	Atomic mass	Mass (g)	Moles	Percent composition
		Carbon				
		Hydrogen				
		Oxygen				
		Calcium				
		Sodium				
		Nitrogen				
		Sulfur				
		Arsenic				
		Mercury				
		Total moles:				

Conclusions:

1. Using the % composition column, draw a graph (bar or pie) that shows the concentration of each element.
2. What is the source of calcium and nitrogen in coal?
3. The bottom three elements, sulfur, arsenic, and mercury are considered contaminants. Are these elements major components of coal?

Activity: Mercury in the Environment

Duration: 3 days

Objective

- Explain the process that results in unsafe levels of mercury in fish.
- Research another environmental toxin and explain the basics of what the toxin is, how it gets into the environment, and what the concerns to humans are.

Materials

- One copy of the Fish Consumption Advisory Warning for each student.
- Copies of relevant papers and articles, bundled to support the subgroups described below.
- One copy of the Summary of the Chemicals of Concern Found in Fish: San Francisco Bay Pilot Study, 1994, for each student.
- Copies of relevant papers and articles, bundled to support the subgroups described below: The Minamata video and a means to show it
  http://science.education.nih.gov/supplements/nih2/chemicals/activities/lesson5.htm
- Overheads or Powerpoint slides to illustrate each of the questions below
- Poster boards and typical art supplies (markers, etc).

Tasks Before Class

- Make paper bundles.
- Prepare overheads or slides.
- Reserve computer lab for Day 3 (or Day 2, see below)

Procedure

Day 1

Step 1 – Introduction Expected Minutes 15:

Hand out a copy of the Fish Consumption Advisory Warning to each student. Allow a few minutes for students to read the warning. Lead a discussion about what the warning means and ask students what they know about the issue. Ask what additional information they would need to understand the issue more fully. Generate a list that resembles the following one. If students have other relevant questions, they may be added.

1. What is mercury?
2. What is mercury used for?

3. How do we get mercury? How is it mined?
4. Where did it come from? How did it get into the bay?
5. How does it get into fish?
6. Why are we concerned only with certain fish?
7. Why is mercury bad for humans?
8. Why is it particularly bad for pregnant women, infants and small children?
9. How do they decide how much is OK to eat?

Step 2 – Group Sessions Expected Minutes 30

Divide the students into groups of three or four. The total number of groups should equal the number of questions. In the case the above list is used without change, this would be nine groups. Each group should be given a packet of articles and papers that contains the answers to their question. Each packet should contain full articles and papers so that students are given practice at scanning articles and searching for relevant information. The teacher should roam the room and make sure that each group is finding the appropriate references. Each group should assign one person to write down the relevant points and select one person to present the information.

Step 3 – Group Presentations Expected Minutes 45

Each group will present in a few minutes the answer to their group's questions. The teacher should be prepared to step in and provide supplemental understanding and to correct any misinformation. Each question will be given approximately five minutes. The teacher should make sure that at least the following information is included for each question. This information provides a basic skeleton of the necessary facts to understand the issues of mercury in our environment and are suitable for all classes. More advanced classes may be provided with more detailed information. But each discussion should eb brief so that the entire flow can be included in one lesson. For advanced classes, details on specific points should be discussed on Day Two.

1. What is mercury?
    a. Mercury is element number 80 and its symbol is Hg
    b. Mercury is a metal.
    c. Mercury is a liquid at room temperature.
    d. Mercury is dense and thus very heavy.

2. What is mercury used for?
    a. Dental Fillings
    b. Electronic components such as switches.
    c. Gold mining

3. How do we get mercury? How is it mined?

a. Mercury is found in very specific spots and is usually in the form of cinnabar.
b. Cinnabar is a combination of mercury and sulfur.
c. Cinnabar is ground up and then heated at high temperatures.
d. Mercury vapor is collected and then sent through tubes to cool and liquefy. The liquid is then collected and put into flasks.

4. Where did it come from? How did it get into the bay?
    a. One of the biggest mercury mines in North America is located at New Almaden.
    b. Small particles of cinnabar are washed down the rivers and flows down Guadalupe Creek into the south part of San Francisco Bay

5. How does it get into fish?
    a. Bacteria in the bay turn mercury into methyl mercury. This form of mercury easily attaches to molecules in the bacteria and in algae.
    b. Fish then eat the bacteria and algae and thus consume mercury.
    c. The process occurs only in anoxic or anaerobic (no oxygen) bacteria that are typically found beneath the surface of mud. The process also requires sulfur. Seawater contains a fair amount of sulfur. You can tell when conditions are right by the rotten egg smell.
    d. The south bay has lots of shallow muddy areas where the conditions are right.

6. Why are we concerned only with certain fish?
    a. Most organisms are not very good at eliminating mercury from their system. So when they consume mercury, it builds up in their bodies. This process is called bioaccumulation.
    b. Big fish eat small fish and thus get the mercury that is in the small fish. The fish like striped bass and sturgeon live a very long time and thus eat a lot of little fish. Over this long life, lots of mercury accumulates. This process of mercury moving up the food chain and increasing in amount is called biomagnification.

7. Why is mercury bad for humans?
    a. Mercury causes problems for the nervous systems of humans.
    b. Mercury appears to bind to enzymes in the body that contain sulfur. This prevents these enzymes from working normally.

8. Why is it particularly bad for pregnant women, infants and small children?
    a. The developing nervous systems of fetuses and infants is especially sensitive to these changes.
    b. That’s why women who are pregnant and those who will be pregnant are especially vulnerable.

9. How do they decide how much is OK to eat?
    a. The EPA has established a safe level of mercury consumption per day.
    b. Different types of fish have been tested to see how much mercury they contain per gram (or ounce) of meat.
    c. If you divide the safe level by the amount per gram, you obtain the amount of fish that contains the safe level.
    d. If you don't eat more than this you should be OK.
    e. But fish contain many healthy things for you like omega-3 fatty acids. So, rather than not eating fish, it is better to eat fish low in mercury.

Step 4 – Closure Expected Minutes 15

Show the five minute movie on the Minamata.disaster. Discuss how it happened and how Japan dealt with it. Discuss issues of government regulation versus individual and corporate freedom. The key should be to discuss trade-offs and choices, not to push an ideology.

Day 2 This is where detailed instruction relating to specific subjects and the processes of the mercury story that are part of that subject.

Day 3 (or 2 if no detailed instruction is inserted for Day 2)
Step 1 – Introduction Expected Minutes 15:

Move the class to the computer or lab (or remain in classroom if equipped with enough computers for all students).Hand out a copy of the Summary of the Chemicals of Concern Found in Fish: San Francisco Bay Pilot Study attached. Allow the students a few minutes to read the information. From this article create a list of environmental toxins (besides mercury) that are of concern to the SF bay area. The list should include:

1. Dioxin
2. PCB's
3. Clordane
4. Dieldrin
5. DDT

Step 2 – Group Sessions Expected Minutes 85

Divide the students into groups (probably 5 per group) and assign each group an toxin from the above list. Each group should individually and as a group collect information from the internet to answer the following questions.

1. What is their toxin?

2. What is it used for?
3. How did it get into the bay?
4. What are the health concerns to humans?

The teacher should roam the class and help each group in turn to find appropriate and reliable Web sites and to understand the information they find.

Each group should prepare a poster board explaining their findings. They also need to create a list of the Web sites from which they obtained their information. The poster board and the list of Web sites should be turned in at the end of the period. The teacher will then verify the accuracy of the information. The teacher should work (if necessary) in subsequent days with each group to correct any misinformation or add key information to their posters in preparation for a presentation to the class.

Step 3 – Closure Expected Minutes 5

Discuss the research process with the class. Ask about whether they were able to find good sites. How did they assess whether a site was reliable? Do they have a lot more questions? What are they?

Day 4 (or 3) This may follow directly after the research above or can be delayed a few days if necessary to allow the teacher to finish correcting any misconceptions on the posters.

Step 1 Group Presentations Expected Minutes 50

Each group will present the information on their poster boards to the class. The teacher should be prepared to supplement and correct any misinformation. Each student should present part of the information.

Final Step - Revisions

FISH - Site-Specific Advisory Information: SF Bay and Delta

San Francisco Bay and Delta Region

- Because of elevated levels of mercury, PCBs, and other chemicals, the following interim advisory has been issued. A final advisory will be issued when the data have been completely evaluated.
- Adults should eat no more than two meals per month of San Francisco Bay sport fish, including sturgeon and striped bass caught in the delta. (One meal for an adult is about eight ounces).
- Adults should not eat any striped bass over 35 inches.
- Women who are pregnant or may become pregnant, nursing mothers, and children under age six should not eat more than one meal of fish per month. In addition, they should not eat any striped bass over 27 inches or any shark over 24 inches.
- This advisory does not apply to salmon, anchovies, herring, and smelt caught in the bay; other sport fish caught in the delta or ocean; or commercial fish.
- Richmond Harbor Channel area: In addition to the above advice, no one should eat any croakers, surfperches, bullheads, gobies or shellfish taken within the Richmond Harbor Channel area because of high levels of chemicals detected there.

FISH - Site-Specific Advisory Information

Summary of the Chemicals of Concern Found in Fish: San Francisco Bay Pilot Study, 1994

In 1994 the San Francisco Bay Regional Water Quality Control Board conducted a pilot study to find out what levels of chemicals are present in sport fish in San Francisco Bay. The study was done to guide pollution control activities by determining what types of chemicals are present and where high concentrations may be occurring. It will also identify what further studies are needed. The pilot study was expanded to provide enough information to perform a preliminary health risk assessment on consuming certain fish species caught in the bay. A health advisory for striped bass had already been in effect for many years based on elevated levels of methylmercury, an organic mercury compound frequently found in fish. The study was thus also intended to determine whether more health advisories should be issued for other fish species that might be contaminated.

The fish in the pilot study were analyzed for about 100 chemicals. Methylmercury and five other chemicals or chemical groups were found to be at levels that were considered high enough to need more investigation. These chemicals include the chlorinated compounds PCBs, dioxins, chlordane, the DDT group, and dieldrin. They are generally associated with industrial activities or agriculture whereas mercury comes from natural and industrial sources. Once these chemicals are released into the environment, they stay there for many years and may be taken up by fish.

The Office of Environmental Health Hazard Assessment (OEHHA) evaluated the potential health hazard of eating fish containing these chemicals. We found that the levels of PCBs, methylmercury, and to a lesser extent dioxins pose a potential health hazard. Eating a few meals of bay sport fish will not make people sick. Our concern is for the potential long-term effects of eating chemically contaminated fish, and especially the potential for harm to sensitive groups such as children and developing young.

We issued an interim advisory recommending that people limit the amount of sport fish they consume from the bay. We also recommended preparation and cooking methods to remove some of the chemicals in the fish.

Because some anglers and their families may be concerned about the potential health effects of the chemicals in this study, we prepared this summary of the six main chemicals named in the study. We report acute toxicity (effects after a single large dose) and chronic toxicity (effects from small exposures over a long time). It is important to understand, however, that the health effects described here often result from much greater exposures than what someone might get from eating sport fish from the bay. The effects described here often result from the high doses given to animals in laboratory tests, rather than exposures to these chemicals in fish. If you are exposed to hazardous chemicals, many factors or circumstances will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), and the other chemicals to which you are exposed. Your individual characteristics such as age, sex, nutritional status, family traits, life style, and state of health are also important factors.

When we developed our interim health advisory for bay sport fish, we took into account as many of these factors as possible. Following the advisory's guidelines will reduce your exposure to harmful chemicals and protect you against harmful effects.

For more information about the health advisories on eating sport fish in California, contact OEHHA, as listed the end of this document. We have prepared other materials on PCBs and methylmercury in fish, which will help explain these chemicals. A summary of the San Francisco Bay study and an illustrated brochure on ways to protect your health when you sport fish are also available.

PCBs (Polychlorinated Biphenyls)

PCBs are mixtures of related chemicals that were sold under the trade name of Aroclor. They were used as transformer fluids, lubricants, hydraulic fluids, and similar products. Their production and use have been banned since 1979. However, these chemicals are still common in the environment where they last a long time and build up in animal tissues. PCBs can be stored in body fat and secreted in milk. The forms with the most chlorine in them tend to last the longest in the environment and in the body. All PCB mixtures change over time. Thus, the PCB mixtures found in the environment are never the same as the products that were actually used. They also differ from the forms used in studies of health effects. These differences complicate evaluation of toxicity.

PCBs are not highly toxic with a single dose. However, there is concern that continued low levels of exposure may be harmful. Effects on the kidneys and the circulatory, digestive, nervous, and immune systems have been seen in animal tests. Effects were also found in children of mothers who ate fish from the Great Lakes. These fish had large amounts of PCBs. In these children, small head size, reduced visual recognition, and delayed muscle development were reported. Young children may be especially vulnerable to PCBs because of the greater sensitivity of their developing nervous systems. Some PCB mixtures have been shown to cause cancer in animal studies. It is not clear whether similar effects will occur from low levels of PCBs in people. The U.S. EPA rates PCBs as "probable human carcinogens" because they have been shown to cause cancer in animals and are, therefore, presumed to cause cancer in humans. They are also listed under California's Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65). This act regulates the discharge into waterways of chemicals that are known to cause cancer or reproductive harm in humans or animals.

Dioxins

Dioxins are also mixtures of chemicals, somewhat similar to PCBs. Dioxins have never had an industrial use. They come from chemical reactions in industrial processes and from incineration of chemicals containing chlorine. Forest fires can produce dioxins, but most of the environmental contamination is believed to be from human activities. The most hazardous form of dioxin is TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), often called simply dioxin. It is a trace component of environmental dioxin mixtures. Dioxins, like PCBs, stay in the environment for a long time.

They build up in the food chain, especially in fatty tissues.

Dioxins have been shown to be extremely toxic in laboratory animal studies. They affect multiple organ systems. Reproductive and developmental effects, cancer, and damage to the immune system have been seen in animal studies. TCDD has the highest cancer potency ever found in animal tests. In animal studies, its toxicity to the reproductive and immune systems also occurs at very low doses.

In humans, exposure to dioxin in the workplace has produced chloracne, a severe skin rash. Although no other human diseases have been clearly linked to dioxin exposure, there is concern that dioxins could produce adverse effects in humans similar to those seen in laboratory animal studies. TCDD is considered a probable human carcinogen by U.S. EPA and is listed under Proposition 65.

U.S. EPA is currently conducting a dioxin review. In the draft study released in 1994 for public review and comment, U.S. EPA suggested that total dioxin exposures may already be at a level of concern in some people. However, environmental dioxin levels appear to be decreasing. Improved controls and changes in manufacturing processes have been put in place. Therefore, the long-term situation is improving.

Chlordane

This is another long-lasting organochlorine chemical. It was used as a pesticide, particularly for termite control in homes. Most uses were banned in 1988. It is still found at significant levels in fish and in fatty tissues of animals and people. Significant levels are also often found in soil around the foundations of homes.

Acute exposure to chlordane affects the nervous system and, at very high doses, causes convulsions. Chronic exposures to chlordane can damage the liver and nervous systems. Such effects have been seen in people who were chlordane applicators. Similar effects were also seen in some people exposed to excessive levels of chlordane in the home.

Animal studies show that prenatal exposure can cause damage to the developing nervous and immune systems. Therefore, fetuses and children may be at greater risk than adults from chlordane exposure. Also, because chlordane accumulates in body tissues, and can be passed through breast milk, children and women with childbearing potential should be especially careful to reduce their exposure to chlordane.

Increased tumor rates were reported in several animal studies. In humans, brain tumors and leukemia have been associated with prenatal and early childhood exposures in several studies. Chlordane is rated as a probable human carcinogen by U.S. EPA and is listed under Proposition 65.

The DDT Family (DDT, DDD, and DDE)
DDT (dichlorodiphenyltrichloroethane) was banned as a pesticide in the U.S. in 1972. Human exposure to DDT from general food sources was about 100 times higher during peak use in the early 1970s than it is now. Due to its extreme persistence, however, DDT residues, including DDD and DDE, still remain in the environment and may be found in fish at potentially harmful levels.

DDT has moderate to low acute toxicity. DDD and DDE have similar effects and are usually combined with DDT for hazard estimates. Low-dose chronic exposure in animals can cause liver damage and disrupt the reproductive and immune systems. Some studies suggest that DDT exposure can result in chromosomal damage, leukemia, and lung cancer in humans. DDT is also suspected of causing spontaneous abortion and premature births in humans. Children may be at more risk than adults because of effects on the developing nervous system. Exposure levels that were thought to be safe may be reconsidered because of new findings on developmental, reproductive, and immune effects, according to a recent U.S. EPA review. DDT and DDE are considered to be probable human carcinogens by U.S. EPA and are listed under Proposition 65. However, their potential cancer potency is relatively low. Attention has recently focused more on their hormonal and reproductive effects.

Dieldrin
This is another of the older organic pesticides. Its use was

slowly phased out in the U.S. between 1974 and 1987. However, dieldrin is still found in soils and sediments because it is a very stable chemical. It also remains for a long time in animal tissues where it builds up in fat. Dieldrin can potentially be very toxic to fish. Dieldrin also comes from the breakdown of aldrin, another banned pesticide.

In humans, acute exposure can cause excess excitability, tremors, convulsions, and liver changes. Liver damage also occurs from chronic exposure. Nervous system changes are also seen in people exposed over a long time. Defects in the developing fetus were reported in animals given very low doses. Dieldrin is considered a probable human carcinogen by U.S. EPA and is listed under Proposition 65. The cancer effect is potent. However, many scientists think it is secondary to dieldrin's strong effects on the liver.

Methylmercury

This organic chemical forms in sediments and in animal tissues from metallic mercury or its salts. Mercury ores are found naturally in several places in northern California. Much of the mercury in waterways is related to past mining activities. Methylmercury builds up in fish, other animals, and in humans. It reacts with proteins and stays in the tissues. Trimming fat from fish will not lower exposure to this chemical as it will for other chemicals.

Methylmercury concentrates in human kidneys. High levels may lead to kidney or circulatory failure. However, damage to the central nervous system can occur at much lower doses after long-term exposure. Tremors, incoordination, and weakness are prominent effects. Very low doses in humans can cause numbness or tingling in the hands or feet. The fetus, infants, and children may be especially sensitive to methylmercury's effects on the nervous system. Problems with mental development and coordination are seen in children of women exposed before and during pregnancy. Methylmercury is listed under Proposition 65 due to its reproductive toxicity.

For More Information

To obtain additional information, contact:

Pesticide and Environmental Toxicology Section (PETS) of

the Office of Environmental Health Hazard Assessment (OEHHA)
1515 Clay St.
16th Floor
Oakland, CA 94612
(510) 622-3170
(510) 622-3218 FAX

or the Sacramento office:

Pesticide and Environmental Toxicology Section (PETS) of the Office of Environmental Health Hazard Assessment (OEHHA)
1001 I Street, P.O. Box 4010
Sacramento, CA 95812
(916) 327-7319
(916) 327-7320 FAX

To obtain a copy of the San Francisco Bay Study, entitled, Contaminant Levels in Fish Tissue from San Francisco Bay, contact:

San Francisco Bay Regional Water Quality Control Board
2101 Webster Street, Suite 500
Oakland, CA 94612
(510) 286-1255

Fish caught in bay contain high levels of contamination EPA warns public to limit intake

- Jane Kay, Chronicle Environment Writer
Thursday, July 24, 2003

Sport fish caught in San Francisco Bay routinely exceed state health guidelines for PCBs, mercury, dioxin and other toxic chemicals, according to the most extensive analysis yet of contamination trends.

The U.S. Environmental Protection Agency reiterated warnings Wednesday that people should limit their intake of bay fish.

"We want to keep the public well-informed of the continuing levels of fish contamination in the bay and urge those who consume the fish to be aware of the state's health advisory," said Alexis Strauss, director of the EPA's water division in San Francisco.

In large enough concentrations, the chemicals can cause a range of health problems, from damaging a growing fetus (mercury) to promoting cancer (dioxin) to impairing the nervous system (PCBs).

The nonprofit San Francisco Estuary Institute in Oakland conducted the study based on data from fish caught in 2000. Its Regional Monitoring Program has collected fish every three years since 1994, targeting seven species that are frequently caught and eaten at seven popular fishing areas.

The locations are Redwood and Coyote creeks in the South Bay, the Oakland Harbor, San Leandro Bay, the San Francisco waterfront, Berkeley and San Pablo Bay.

The fish in the study are white croaker, shiner surfperch, leopard shark, California halibut, white sturgeon, striped bass and jacksmelt. Northern anchovy, salmon, brown smooth-hound shark and several other species of surfperch will be added for another round of tests this summer.

The study indicates that fish size and fat content are important factors in the amount of accumulation. Fattier fish species such as shiner surfperch and white croaker showed higher levels of PCBs, dioxins, DDTs, chlordanes (a pesticide) and PBDEs (a flame retardant). Most larger fish species, particularly leopard shark, showed higher levels of mercury contamination, the study found.

Among the other results:

-- PCBs were found in 90 percent of the samples at levels exceeding a state-determined health threshold, dioxins in 69 percent, mercury in 38 percent, dieldrin (a pesticide) in 19 percent and DDT in 4 percent. Selenium, monitored only in sturgeon, was found in 17 percent of the samples.

The benchmark is set to alert scientists that there may be a health risk for people consuming the fish and that more study is warranted.

-- DDT and chlordane in white croaker declined from levels found in the 1980s, while levels of selenium remained the same. Mercury levels didn't drop in striped bass from the 1990s when compared with bass from the early 1970s.

Mercury leaks into the bay from abandoned mercury and gold mines. It also falls into the bay in the form of air pollution from fossil fuel combustion. Mercury is also found in bleach and dental amalgams. Dioxins are released during combustion involving diesel trucks, wood burning and medical, hazardous waste and garbage incinerators. PCBs, once used in electrical transformers, and DDT, once used as a pesticide, persist decades after they were banned. . The full report is on the Web at www.sfei.org. The state's fish advisories can be found at www.oehha.ca.gov/fish.html.

FISH WARNING

State advisories say adults should limit consumption of bay sport fish to, at most, two meals per month, and eat no striped bass longer than 35 inches.

Pregnant women, or women who may become pregnant or are breast feeding, and children under 6 shouldn't eat more than one meal per month of bay fish. These groups shouldn't eat any striped bass longer than 27 inches or shark longer than 24 inches.

There are no advisories on salmon, anchovies, herring or smelt caught in the bay. These species are not exposed to the same levels of contaminants because they spend much of their life outside the bay in the ocean.

ACTIVITY: BIOACCUMULATION AND FOOD CHAINS

DURATION: 2 hours

OBJECTIVES

- To describe bioaccumulation and biomagnification.
- To explain the impact that bioaccumulation can have on consumers
- To model how levels of contaminants change throughout a food web.

MATERIALS

- Handout for students
- Tokens – approximately 2/3 not red, 1/3 red (I used Bingo Chips)
- Animal Cards – adjust these to fit your class size, make sure you have more prey than predators
    - 2 large predators
    - 5 walleye
    - 8 rainbow trout
    - 20 zooplankton

BACKGROUND

In the late 1960s, the government became aware that harmful substances were entering the food web. Some of these substances include: DDT, lead, dioxin, PCBs, PAHs, and heavy metals such as mercury. These substances are called contaminants and last a long time in the environment. In large quantities, these contaminants are harmful to organisms' health (including humans who eat organisms with high concentrations of these pollutants in them).

Organisms store these contaminants in their fat cells and are not released until the fat is burned and even then some remains. Usually, organisms lower in the food chain do not bioaccumulate very many contaminants. However, when an organism consumes many of these lower species it also consumes the contaminants that are in it. That is what is meant by bioaccumulation – how contaminants enter and get passed along in a food chain. Obviously, the higher up the food chain an organism is, the greater the bioaccumulation. This is called biomagnification. So, higher level consumers have the greatest chance of having a lot of contaminant bioaccumulate in their bodies.

Contaminant	Explanation	Come From	Used For	Health Effects
DDT	Dichloro Diphenyl Trichloroethane	chlorinated hydrocarbon	insecticide	low toxicity to humans
PCB	Polychlorinated Biphenyl	transformer coolant, insulation	no longer used	brain defects, cancers
PAH	Polynuclear Aromatic Hydrocarbons	petroleum products	by-product	carcinogenic (causes cancer)
Heavy Metals	mercury, lead, copper, zinc	mining, metal processing	by-product	harms nervous system and reproduction

Procedure

1. Each student will be assigned a different role for the ecosystem.

2. Your role is described below:
   a. Zooplankton → pick up a token from your teacher, if you are eaten, return to “home base,” pick up another token and head back out
   b. Rainbow Trout → you eat zooplankton, when you “eat” zooplankton, place their tokens into your stomach; if you are eaten, return to “home base” and then head back out.
   c. Walleye → you eat rainbow trout, when you “eat” the rainbow trout, place their tokens into your stomach; if you are eaten, return to “home base” and then head back out.
   d. Eagle/Raccoon → you eat walleye, when you “eat” the walleye, place their tokens into your stomach.

3. When you group is released, begin feeding (zooplankton will just begin walking around). You must stay in the designated area. You will “eat” your prey by tagging them. When you “eat” your prey, take their tokens.

4. Continue feeding until time is up. When time is up, return to the classroom and add your information to the class data record sheet.

5. Next, answer the questions in the analysis & investigation section.

Analysis & Investigation

1. How much mercury did you have in your stomach (how many red tokens did you have in your cup)?

2. Create a bar graph of how much mercury each species had in their stomach (we will use the average amount for each species). Species will be listed on the X-axis; amount of mercury will be on the Y-axis.

3. The Sport Fishing Consumption Guide places restrictions on eating fish with certain amount of mercury in them (for health reasons, we will learn about this later). The guide is as follows:

Unrestricted Consumption	Limited Consumption		No Consumption
	200g of fish per week	140g of fish per week	
less than or equal to .0005g/kg	.005 g/kg to .001 g/kg	.001 g/kg to .0015 g/kg	over .0015 g/kg
one red token or less	two red tokens	three red tokens	Four red tokens or more

a. Determine how many fish are in each of the categories in the chart above

b. Calculate the percentage of fish in each category

Unrestricted Consumption	Limited Consumption		No Consumption
	200g of fish per week	140g of fish per week	
______ fish	______ fish	______ fish	______ fish
_______%	_______%	_______%	_______%

c. Were you safe to eat (when the game ended)? Why or why not?

4. Create a food chain for the organisms in this activity. For each organism, write the average amount of mercury (number of tokens) found in each next to the organism.

5. What do you notice about the amount of mercury at different trophic levels (feeding levels of the food chain)?

6. Humans also eat walleye. Add humans to your food chain. What sort of mercury levels would you expect to see in the human and why?

7. Panthers eat raccoons. Add panthers to your food chain. What sort of mercury levels would you expect to see in the panther and why?

8. We determined how much mercury was in each "fish" by looking at its stomach's contents. However, anglers and fishermen cannot examine the fish's stomach without harming it so they need another way of determine if a fish is edible, that is, it contains low amounts of mercury. It is known that the larger the fish, the greater the chance of bioaccumulation. This is because bigger fish have eaten more food and the risk of accumulating mercury increases. Thus, the Sport Fishing Consumption Guide has found that certain amounts of mercury in fish corresponds to the size of that fish for specific species. The following is a chart that shows what size of fish is suitable for consumption.

Fish Species	Unrestricted Consumption	Limited Consumption		No Consumption
		200g of fish per week	140g of fish per week	
Walleye	under 41 cm	41-51 cm	51-58 cm	over 58 cm
Channel Catfish	under 59 cm	59-72 cm	72-80 cm	over 80 cm

a. The following is a list of fish caught. The people that caught would like to know if these fish are suitable for eating. Use the chart to categorize these fish

➢ Channel Catfish: 73 cm	➢ Channel Catfish: 83 cm
➢ Channel Catfish: 57 cm	➢ Walleye: 57 cm
➢ Walleye: 41 cm	➢ Channel Catfish: 60 cm
➢ Walleye: 58 cm	➢ Walleye: 30 cm
➢ Channel Catfish: 50 cm	➢ Walleye: 40 cm
➢ Walleye: 59 cm	➢ Channel Catfish: 67 cm
➢ Channel Catfish: 45 cm	➢ Walleye: 42 cm
➢ Channel Catfish: 53 cm	➢ Channel Catfish: 71 cm
➢ Walleye: 47 cm	➢ Walleye: 50 cm
➢ Walleye: 37 cm	➢ Walleye: 43 cm

Fish Species	Unrestricted Consumption	Limited Consumption		No Consumption
		200g of fish per week	140g of fish per week	
Walleye				
Channel Catfish				

9. Answer the following questions about the chart above:

a. If these people never eat more than 140g of fish per week, how many of the fish they caught are safe for them to consume?

b. If these people eat more than 200g of fish per week, how many of the *catfish* they caught are safe for them to consume?

c. If these people never eat more than 200g of fish per week, how many of the walleye they caught are safe for them to consume?

d. How many of the fish are totally unsafe to eat, no matter how much they eat per week?

10. Thinking about what you have learned, answer the following question: Why is there a limit on the amount of tuna that you should eat?

Teacher Notes

Materials:

Tokens – approximately 2/3 not red, 1/3 red (I used Bingo Chips)

Animal Cards – adjust these to fit your class size, make sure you have more prey than predators

- 2 large predators
- 5 walleye
- 8 rainbow trout
- 20 zooplankton

Prey are eaten when tagged by a predator.

First – Release plankton into the environment, begin walking around. If plankton are eaten, they can return and pick up a new token.

After a couple minutes - rainbow trout are released into their environment. Give rainbow trout a couple minutes to begin to eat zooplankton. *If rainbow trout are eaten, they can return to "home base" and head back out to feed again (simulating new offspring)*

After a couple more minutes, walleye are released into their environment.

Finally, release the predators.

At the end of time, return to the classroom and record and analyze data.

Resources

http://www.pbs.org/newshour/extra/teachers/lessonplans/science/merc_environ_h2.pdf

http://www.hallofhealth.org/sepa/lesson_plans/environmental%20toxics/4th_gr_toxics_lesson_2.pdf

http://www.hallofhealth.org/sepa/lesson_plans/environmental%20toxics/4th_gr_toxics_lesson_3.pdf

http://www.thinkport.org/Tools/ContentViewer/ContentPreview.aspx?ContentID=3fd0d5b7-8dc9-4dac-ac33-ec0701fd99cd

http://hsc.unm.edu/pharmacy/iehms/docs/QS%20Science.pdf

http://www.usgs.gov/themes/factsheet/146-00/

http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115644.htm

http://www.americanpregnancy.org/pregnancyhealth/fishmercury.htm

http://water.epa.gov/scitech/swguidance/fishshellfish/fishadvisories/advisories_index.cfm

http://science.jrank.org/pages/854/Bioaccumulation.html

http://www.marietta.edu/~biol/102/2bioma95.html

http://www.pollutionissues.com/A-Bo/Bioaccumulation.html

http://en.wikipedia.org/wiki/Biomagnification

http://web.ead.anl.gov/ecorisk/fundamentals/html/ch2/2.2.htm

http://www.sciencedaily.com/releases/2009/08/090818150020.htm

http://my.epri.com/portal/server.pt?open=512&objID=387&&PageID=225890&mode=2&in_hi_userid=2&cached=true

http://emsi-teacherworkshop.stanford.edu/pages/lessons.html