CRITTER CONTAMINATION

Grade Level: 7 - 12

Subjects: Math, Social Studies, Science, Geography

Duration: 60 minutes

Group Size: Individual

Setting: Classroom

Key Vocabulary:
PCB, bioaccumulants, bioconcentration, biological magnification (biomagnification)

Materials:
- *graph paper*
- *PCB data and time line handouts*
- *Map of the Mississippi River*

OBJECTIVES

Students will be able to:

1. understand how PCBs entered into the environment;
2. describe how they bioconcentrate in an animals body;
3. observe that pollution and contamination problems (i.e. PCBs) are not evenly distributed along the Upper Mississippi River
4. Describe one reason pollution and contamination problems (i.e. PCBs) are not evenly distributed along the Upper Mississippi River.

METHODS

Students graph actual PCB concentrations in mayflies living in the Upper Mississippi River.

Bioaccumulants: 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. (See: biological magnification.)
Bioconcentration: The accumulation of a chemical in tissues of a fish or other organism to levels greater than in the surrounding medium.
Biological Magnification (biomagnification): 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. (See: bioaccumulants.)

Definitions from the Environmental Protection Agency's "Terms of the Environment" http://www.epa.gov/OCEPAterms/

BACKGROUND

Surveys of people living along the Mississippi River show that water quality is one of their primary concerns regarding the health of the ecosystem and the health of humans. While pollution and contamination of the Mississippi River is widespread, it is not evenly distributed.

The hotspots of contamination typically occur downstream of large urban areas and areas of industry. Sometimes, the contaminated areas are adjacent to the source in either the sediment or water. For example, contaminants that are in suspension in the water will be most concentrated near the source. As this contaminated water mixes with "clean" water from the Mississippi River or its tributaries, it becomes more diluted and less concentrated. While this does not necessarily result in removal of the contaminant, dilution can reduce the danger it poses to the environment or humans.

Sometimes the contamination can occur several miles downstream. This is common with contaminants that can bind to sediment (silt and clay) suspended in the

water. Sediment in the water can stay in suspension until the current of the river slows down. When the water current slows, such as the lower end of a pool or in a backwater lake, the silts and clays settle to the bottom of the river. Overtime, the deposition of silt and clay (a process called sedimentation) may result in an accumulation of contaminants that were attached to the sediments. One group of contaminants that readily attaches to clay and silt particles suspended in the water column are Polychlorinated Biphenyls (PCBs).

The burrowing mayfly (Hexagenia bilineata) is a pollution sensitive bottom-dwelling organism that is relatively abundant in the Upper Mississippi River. The nymphs of this species live in the silty substrate of the river for about 1 year before emergence. Mayflies play an important role in the introduction of PCBs to the food chain. Since PCBs attach to particles suspended in the river they eventually settle out and are buried in the bottom sediments. As bottom-dwelling mayflies feed, they inadvertently consume the PCBs as well as absorb them from the sediment through there body. **The PCBs concentrate in the fatty tissues of the mayfly nymph and pass them back into the food chain when fish eat the mayflies**. Chemical analysis of mayflies is an excellent way to determine the potential hazards of PCB transfer and biomagnification in the river food web.

Sampling of mayfly nymphs and analysis of PCB concentrations in their bodies is one method to monitor the extent of PCB contamination in the environment. This method also is used to identify "hotspots" of PCB contamination along the Mississippi River since mayfly nymphs are sedentary, spending the entire nymph stage in a single location.

Top View - Adult

Top View - Nymph or Naiad

Side View - Adult

From: http://www.ag.ohio-state.edu/~ohioline/hyg-fact/2000/2166.html

What are PCBs?

PCBs are man-made chemicals that are colorless and odorless. Up until the late 1970's PCBs were widely used industrial chemicals because of the nature of their chemical and thermal stability. PCBs were used in fluorescent light fixtures, carbonless paper, adhesives, plastics, paints, varnishes and sealants, as well as for coolant insulation fluids in electrical equipment. The United States produced 1.5 billion pounds of PCBs between 1930 and 1975. Unfortunately, PCBs were later found to be dangerous chemicals. Their stable tendencies prevent their breakdown into less toxic chemicals and consequently PCBs are quite persistent in the environment. As a matter of fact, PCBs are currently the river contaminants of greatest concern for Minnesota, Wisconsin, and Iowa.

Prolonged exposure to even small concentrations of PCBs can lead to health problems such as liver damage, cancer, and growth and developmental problems. In 1977, Monsanto Chemical Company, the sole producer of PCBs in the United States, stopped the manufacture of the chemical. The Toxic Substances Control Act banned the manufacture of PCBs in open systems in 1979.

Monitoring has shown the presence of PCBs throughout the country, including areas isolated from PCB manufacturers. The chemicals periodically escape during spills or when old equipment is discarded. When PCBs leach out of the landfills they end up in our rivers, lakes and air (through evaporation). Once these chemicals enter the aquatic environment, they are incorporated into the food chain, becoming progressively more and more concentrated in the upper levels of the food web. This process is called biomagnification.

PCBs not only enter the food chain, they bioconcentrate within it. These chemicals are bioaccumulants. They are not metabolized and eliminated following their ingestion. Instead, **PCBs build up in an organism's fat and tissues over time**. For example, when a fish feeds in a PCB contaminated system, the level of PCBs it carries in it's body will increase with every meal. Since the fish releases the chemical very slowly from it's body, the longer it survives and the longer it feeds upon contaminated food sources, the greater the PCB burden becomes. Should a fish burdened with PCBs be eaten by a predator, the predator's health is also jeopardized. The predator is further threatened by the probability that it is feeding upon other fish that are also contaminated. With each meal it is acquiring the full dose of the chemical burden of its prey, and consequently adding increasingly larger amounts of PCBs to its own body.

People can reduce their exposure and ingestion of PCBs by checking Fish Consumption advisories issued by state natural resources agencies and following the consumption guidelines. These guidelines include the recommended number of fish meals adults and children can consume from areas of the Mississippi River where fish have been found to be contaminated with PCBs or other forms of pollution. The guidelines also include information on how to clean fish to remove most of the fatty tissue where PCBs and other contaminants tend to concentrate.

MATERIALS

- graph paper
- PCB data (1/student)
- time line (1/student)
- copy of Upper Mississippi River Map (1/student)

PROCEDURES

1. Tell the students that today they will be focusing on one group of contaminants, PCBs. Share with them what PCBs were used for and why they persist in the environment. Explain to them that PCBs have been used for a long time until they were found to be detrimental to the environment and humans (you may want to use the time line at the end of this activity to lead this discussion and/or you may want to make a copy of page WQ 25 as a handout).

2. Provide students with the data from Table 1. Explain to them that PCB contamination can be measured indirectly through the amount of PCB present in mayfly nymphs. The mayflies represent a species that is sensitive to pollution and can be used as a bio-indicator of certain types of pollution. Mayflies accumulate PCBs in their fatty tissues through feeding and respiration. Have them graph concentration versus river mile (use river mile on the x-axis and concentration on the y-axis, see example on page WQ 32). You may want to make an overhead of this graph for students to check against and for classroom discussion.

River miles on the Upper Mississippi River measure the distance above the mouth of the Ohio River (the Ohio River forms the southern boundary of Illinois). Therefore, the Mississippi River mile at the mouth of the Ohio River is 0.0. The distance is displayed on signs along the river.

3. Ask the students to hypothesize reasons for peaks in PCB concentrations along the River.

4. Next, using the map of the Mississippi River on page WQ 30, have them look for the cities which are shown in Table 1. They should note that higher levels of PCBs usually occur near or downstream of population centers where industrial uses of PCBs were more prevalent. The downstream impact can be several miles (i.e. the higher levels at Hastings, Diamond Bluff, and Lake City are from sources near St. Paul, MN.) Elevated levels near Buffalo City may be associated with power plants at Alma, WI.

   The reason there is no peak near St. Louis is that this database did not include any samples downstream of St. Louis. If it had, a peak of PCB would have been seen further downstream.

DURING ASSESSMENT

Assess the thoroughness and accuracy of the graph.

POST ASSESSMENT

1. A group of fishery biologists studied the presence of a toxic chemical in a lake. They discovered the water had one molecule of chemical for every one billion molecules of water. This is called one part per billion (1 ppb). The algae had one part per million (1 ppm) of the toxic chemical. Zooplankton (small animals) had 10 ppm. Small fish had 100 ppm. Large fish had 1,000 ppm. How do you explain this increase in this toxic chemical to 1,000 ppm for the large fish? The biologists found the chemical was a pesticide that had been sprayed on cropland 100 miles away from the lake. How did so much of it get into the lake? (The pesticide got into the though runoff. The large fish has a higher level of the chemical in its body due to bioaccumulation. The larger fish eats greater quantities of food and has more fatty tissue and consequently accumulates greater quantities of the chemical.)

2. Why do PCBs continue to be a problem in our environment when they were banned nearly 20 years ago? (PCBs continue to be released into the environment via spills, leakage and disposal of equipment containing PCBs. Resuspension of PCBs into the water column also occurs due to the feeding activities of fish and wildlife or wave action.)

3. In what portion of the body do PCBs tend to concentrate? (PCBs tend to concentrate within an organisms fatty tissue.)

4. How might one reduce his or her risk of exposure to PCBs when cooking fish? (Remove all traces of skin and fat before cooking and eat smaller, leaner fish.)

5. Why do PCB concentrations change along the length of the Mississippi River? (Higher concentrations are in areas downstream of urban areas where the silts and clays PCBs are "attached to" settle out of the water column.)

EXTENSIONS

1. To demonstrate biomagnification in an aquatic food chain of the Mississippi River, do the activity Moving Up the Food Chain included in this guide.

2. Have students fill in the location of the cities along the Mississippi River using an atlas before proceeding with step four in the procedures. (A blank Mississippi River map is provided on page WQ 31.)

WHAT HAPPENED WHEN

1929 PCBs manufactured in the US under trade name "Aroclor" by Monsanto Industrial Chemicals, Inc. for industrial uses.

1966 PCBs identified as a problem in Sweden.

1968 Over one thousand people seriously poisoned by PCBs in Yusho, Japan.

1971 Presence of PCBs reported in Lake Michigan.

1972 Monsanto voluntarily restricts sale of PCBs to manufacturers of "closed" electrical and hydraulic systems, such as transformers.

1973 By this date more than 400,000 tons of PCBs have been produced in the US, none of which have been destroyed. PCBs found in all forms of life, even aquatic organisms 11,000 ft. below sea level.

1973 Food and Drug Administration establishes temporary tolerances for PCBs in food. For most fish eaten by humans, the level is 5 ppm.

1975 EPA estimates that 50% of all US residents had 1-3 parts per billion of PCBs in their body tissue.

1975 PCB conference in Chicago brings about recognition of the need for further action against PCB contamination.

1976 The Toxic Substances Control Act bans manufacture of PCBs and their use except in closed systems like electrical transformers and capacitors (exemptions were authorized for certain open uses).

1977 FDA proposes reduction in temporary tolerance levels of PCBs in fish from 5 ppm to 2 ppm due to increasing evidence of health risks. Would result in $49 million loss to the fishing industry. Reduction not implemented.

1977 Monsanto ceases manufacturing PCBs, ending US production.

1979 Regulations issued under the Toxic Substances Control Act prohibit the sale, manufacture, distribution and use of PCBs in open systems.

1980 Between 1929 and 1980 1.4 billion pounds of PCBs were produced. Some 500 million pounds have ended up in improper dumping grounds leading to widespread PCB dispersion in the environment.

1980 Fish advisories in effect in six of the Great Lakes states due to contamination with PCBs. Canada prohibits sale of fish with 2 ppm or more PCBs.

1984 All non-totally enclosed uses of PCBs banned.

1995 PCBs in totally enclosed uses are gradually being taken out of service due to wear and tear, etc.

Table 1. Concentration of PCBs in emergent female mayflies from the Upper Mississippi River, collected in 1988 by pool and river mile, dry weight normalized.

CITY	POPULATION OF SECECTED CITIES	POOL	RIVER MILE	TOTAL PCBs (ppm dry wt)
Little Falls, MN	7,232		968.7	0.23
St. Paul, MN	272,235	2	836.3	1.12
Grey Cloud, MN		2	825.0	4.10
Hastings, MN	15,445	2	815.2	3.89
Diamond Bluff, WI		3	796.8	3.53
Lake City, MN	4,433	4	775.1	2.53
Alma, WI	790	4	752.8	0.90
Buffalo City, WI	915	5	745.5	1.78
Winona, MN	26,286	5a	728.6	1.02
Trempealeau, WI	1,039	6	714.1	1.23
Genoa, WI	266	8	679.2	0.50
Lansing, IA	1,012	9	655.8	0.50
Guttenberg, IA	1,987	10	615.0	0.45
Dubuque, IA	57,686	11	583.0	0.26
Savanna, IL	3,542	12	550.0	0.49
Clinton, IA	27,772	13	522.6	0.33
Moline, IL	43,768	15	483.0	2.14
Drury, IL		16	457.2	0.68
Mercer County, IL		17	437.1	0.45
Oquawka, IL	1,539	18	410.5	0.38
Canton, MO	2,623	20	343.2	0.47
Quincy, IL	40,366	21	325.0	0.39
Cincinnati, IL		22	301.0	0.46
Batchtown, IL		25	241.0	0.21
Machens, MO		26	211.0	0.55
St. Louis, MO	396,685	27	185.5	0.41

Data in table obtained from USGS, Upper Mississippi Environmental Sciences Center, La Crosse, WI.


Mississippi River
Little Falls
St. Paul
Mississippi R. River
Grey Cloud
Hastings
Lake City
Diamond Bluff
Alma
Buffalo City
Trempealeau
Goodview
Genoa
Lansing
Guttenburg
Dubuque
Savanna
Clinton
Moline
Drury
Mercer County
Oquawka
Illinois River
Canton
Quincy
Cincinnati
Batchtown
Missouri River
Machens
Missouri River
St. Louis
Ohio River


Mississippi River
Illinois River
Missouri River
Missouri River
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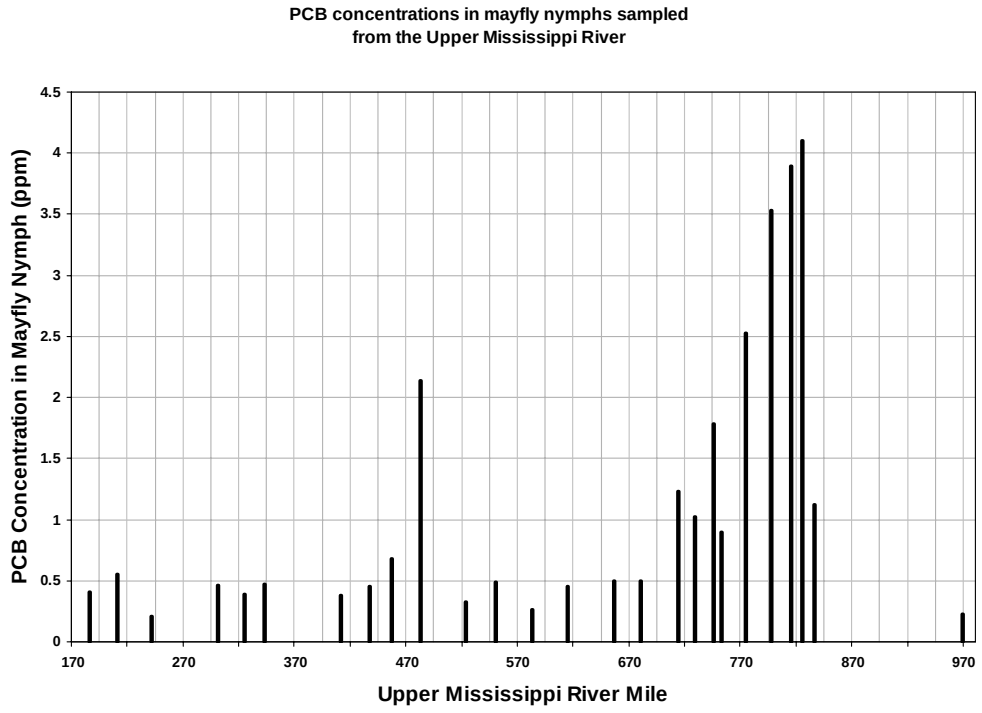

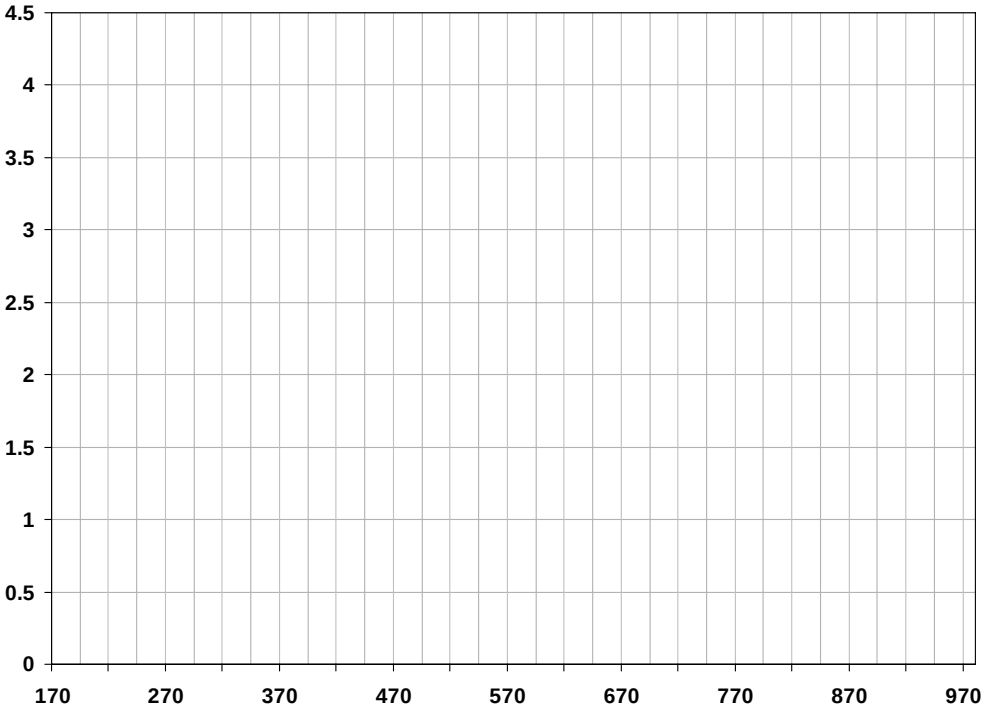

Example of graph and blank graph for Critter Contamination.